July/Aug. 1958
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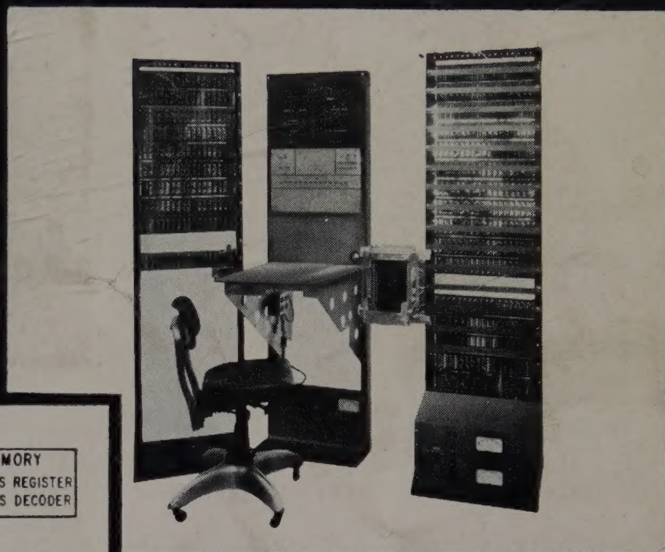

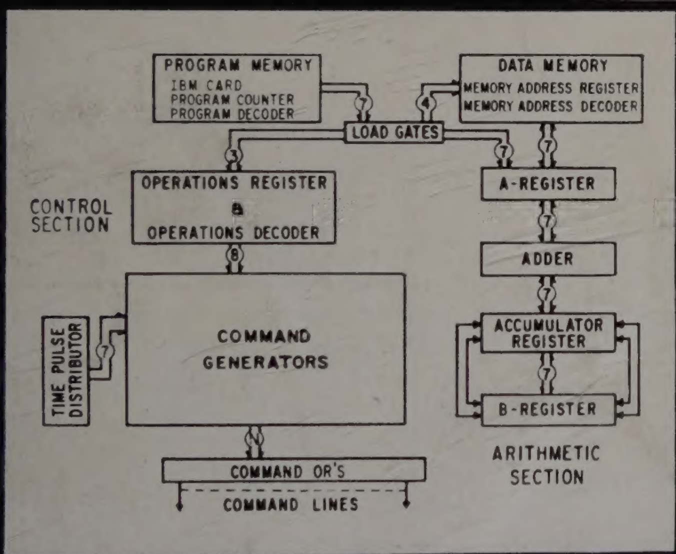

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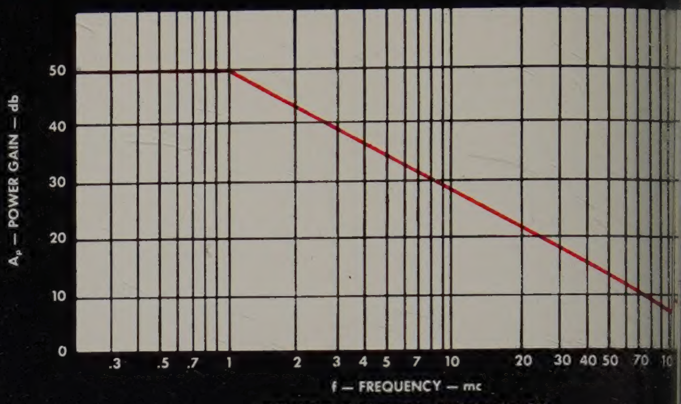

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maximum ratings at 25°C

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collector to emitter	
emitter to base	
total dissipation	

typical design characteristics at 25°C

	(conditions)	
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emitter reverse current	$I_C = 0$	$V_{EB} = -0.5V$
forward current transfer ratio	$I_C = -2mA$	$V_{CE} = -6V$
current transfer ratio cutoff frequency	$I_C = -2mA$	$V_{CB} = -6V$
max. frequency of oscillation	$I_C = -2mA$	$V_{CB} = -6V$
frequency where h_{fe} is unity	$I_C = -2mA$	$V_{CB} = -6V$

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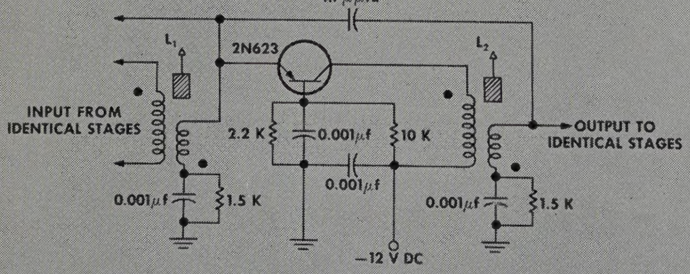
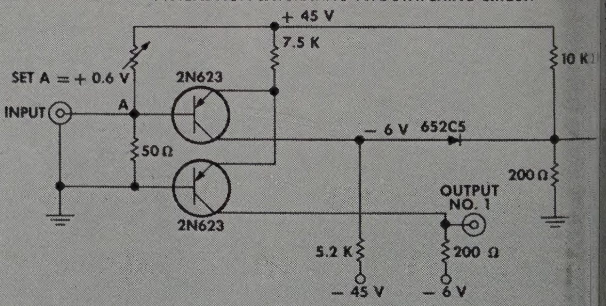
APPLICATION NOTES

TYPICAL 43 MC IF AMPLIFIER



TYPICAL VALUES — AVAILABLE POWER OUTPUT 20 mW (PEAK)
NOISE FIGURE 6 db • POWER GAIN 15 db • BAND WIDTH, ONE STAGE 11 mc
APPROX. IMPEDANCE LOOKING INTO PRIMARY 56 Ω • LOAD ON SECONDARY 3000 Ω

TYPICAL NON-SATURATING TYPE SWITCHING CIRCUIT



TYPICAL SWITCHING TIMES OBTAINED IN ABOVE CIRCUIT
t_{on}: 14 mμsecs t_{off}: 14 mμsecs
(INCLUDES OSCILLOSCOPE RISE TIME)

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SEMICONDUCTOR PRODUCTS

SANFORD R. COWAN, Publisher

July/August 1958 Vol. 1, No. 4

Front Cover

The front cover shown this month depicts a physical view and a block diagram of a high speed digital computer for military applications developed by the Military Products Division of IBM. The transistorized pulse circuits for this equipment are described in an article beginning on page 26.

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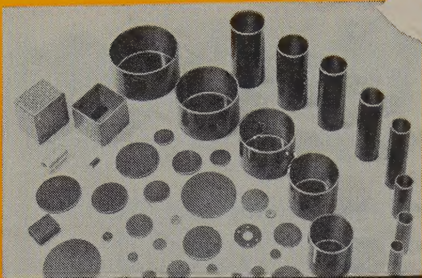

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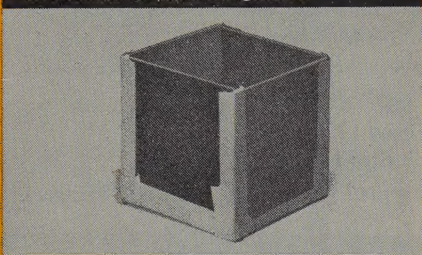

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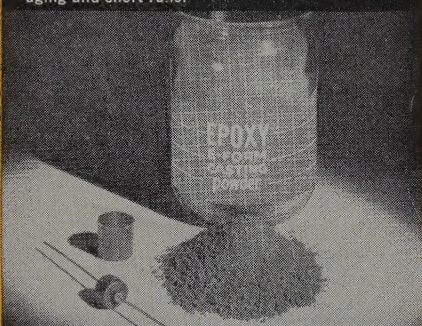

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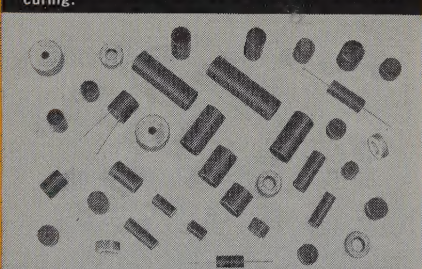

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ditorial . . .

Transistor Issue

pproximately six years have passed since the first nsistor Issue of the Proceedings of the IRE. At time a complete issue was set aside to describe les made on a new active device over a four year od. In commemoration of the tenth anniversary e discovery of the transistor the Proceedings of IRE has published one of its biggest issues, again ng tribute to a rapidly growing transistor indus- Transistor developments and the transistor in- try have made great inroads into electronics espe- ly since the initial November 1952 issue of the ceedings of the IRE.

t this time we choose to look back to the famous vember 1952 issue of the Proceedings of the IRE view the evolution of the "state of the art." This lution is indicated by the second Transistor Issue une 1958 which undoubtedly will be considered as important reference issue in its own right.

canning the November 1952 Proceedings it cannot denied that it contained much information the point contact transistor which today is con- ered obsolete, mechanically, but whose electrical racteristics device designers are, in part, attempt- to reproduce through the medium of new devices. addition, there were items in the initial issue on ction transistors, which today are the foundation of st devices fabricated. High frequency junction tran- tors had alpha cut-off frequencies of less than 30 *mc;* vices were fabricated from germanium material for e most part; and device material considerations did t extend much beyond silicon and germanium.

The June 1958 issue of the Proceedings indicates e almost universal use of germanium and silicon. owever, an article appears on intermetallic com- und research in relation to transistors. Frequency- ise indications of 500-1000 *mc* alpha cut-off frequen- es are presented which are almost a two order of magnitude change in this characteristic over that indicated six years ago. With respect to a transistor figure of merit based on a power frequency combination expressed in watt-megacycles, there are indications of figures of 50-70 watt-megacycles for silicon and germanium devices respectively. The mention of point contact transistors appears to have been completely displaced by junction devices fabricated by alloy and diffusion processes. Although the mention of point contact transistors has disappeared, the search for regenerative devices continues and articles on p-n-p-n devices appear.

It is of interest to compare the two transistor editions of the Proceedings of the IRE and envision the growth and potential of a relatively young field. In the light of the rapid changes that have occurred in a little over half a decade, as evidenced by these two issues, it is difficult to predict what the next "Transistor Issue" will describe.

SCP To Go Monthly

When SEMICONDUCTOR PRODUCTS was originally launched this year, we planned to publish the magazine bi-monthly until the industry showed signs of needing more frequent issues. That situation already exists, as indicated by the vast increase of excellent editorial material and technical articles we are receiving. In order to make as much as possible of this material available to our readers we are proud to announce that effective January 1959 SEMICONDUCTOR PRODUCTS will appear every month. In addition, we plan new departments and columns that will further enhance the value of this magazine to scientists and others engaged in the semiconductor industry. One such column inaugurated in this issue is "Research News," the purpose of which is to provide the reader with up-to-date information on a research level.

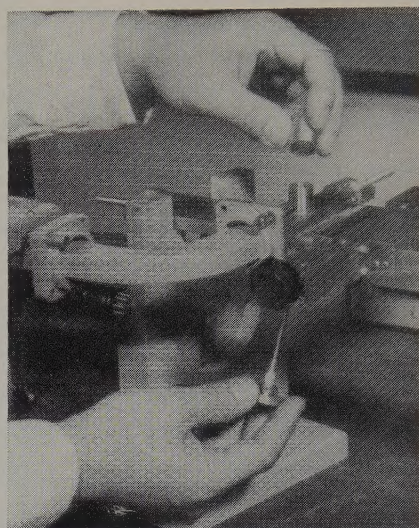
Samuel L. Marshall

Research News

Research laboratories are invited to contribute items of interest to this column.

A new device which has exciting possibilities as a low-noise *u-h-f* and microwave amplifier is under development at Bell Telephone Laboratories. Although still in the experimental stage, preliminary results indicate that this device, which uses semiconductor diodes as the active elements, can improve the performance of many types of microwave receivers. It is relatively simple to construct and operate, and shows prospects of having a long life.

Noise is a major problem in the amplification of weak microwave signals. Commercially available amplifiers and converters add a considerable amount of noise to the incoming signal, thus decreasing the sensitivity of the receiving equipment. A major reduction in this added noise can significantly improve the performance of radio receivers such as those used in radar, radio astronomy, over-the-horizon radio relay and *u-h-f* television sys-



Equipment for studying the amplifying properties of a nonlinear capacitor semiconductor diode. The right hand is holding the special diode and enclosure, and is about to insert it in the proper location in the waveguide structure. A pump frequency of 12,000 magacycles enters from the left. The signal, in this case 6,000 megacycles, comes in from the right, is amplified and reflected back back inside the same waveguide. The incoming and outgoing signals may be separated by a ferrite microwave circulator.

tems. The diode amplifier holds promise of providing such a noise reduction.

This amplifier is one of a family of devices known as variable reactance amplifiers in which a variable reactance, or "varactor," serves as the active component. In the present device, the variable reactance is provided by a semiconductor diode (varactor diode) whose capacitance varies with the applied voltage. As with other varactor amplifiers, the applied voltage is derived from a high-frequency pump signal. This signal causes the diode to function as a time-varying capacitance and supplies the energy which is necessary to produce amplification. Low-noise amplification using varactor diodes was predicted by A. Uhlir, Jr. of Bell Laboratories.

Amplification at 6000 megacycles was first demonstrated by M. E. Hines and H. E. Elder of Bell Laboratories. At the same frequency, G. F. Herrmann and M. Uenohara later obtained a bandwidth of 8 megacycles with a noise figure of 5 to 6 db. Gain was 18 db and the pump signal 12,000 megacycles. Gain can be traded for additional bandwidth if desired, and vice versa.

A traveling-wave amplifier configuration using arrays of several diodes shows promise of providing bandwidths of 25% or more in the u.h.f region. Using four stages with the special diodes in such an array, R. S. Engelbrecht of Bell Laboratories has obtained a bandwidth of 100 megacycles at a 400-megacycle signal frequency, with a pump frequency of 900 megacycles and a pump power of 10 milliwatts. This experimental amplifier has a gain of 10 db and a noise figure of only 3½ db.

A single type of diode can be used to make an amplifier for any desired frequency from the high microwave region down to *d-c*. The noise performance improves rapidly as the frequency decreases from microwaves down into the *u-h-f* region, thus making such an amplifier potentially useful for *u-h-f* television receivers.

Interesting aspects of the diode amplifier are its simplicity and potential reliability. Major components are the proper waveguide structures, the diode itself, and a suitable pump signal source. It appears that these components can be assembled to provide a relatively inexpensive device. No refrigeration is required and no magnetic fields are necessary. The low-noise characteristics are realizable at room temperatures.

Although the variable capacity effect is present in commercial diodes, Bell Laboratories' scientists have developed, under a Signal Corps contract, special diffused silicon diodes to maximize this effect. Series resistance, which could be a source of noise, is minimized in these diodes. Units fabricated by N. G. Cranna of the Laboratories have an active diameter of about .002 inch.

The development of the varactor diode amplifier holds promise of providing a whole new family of low-noise amplifiers for the *u-h-f* and microwave frequency ranges. These devices will complement the semiconductor diode up-converter recently announced by Bell Laboratories, which can also provide low noise amplification.

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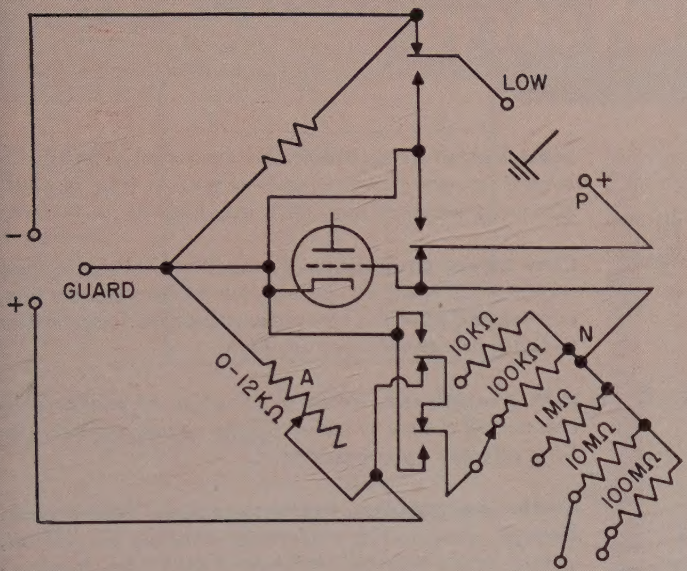

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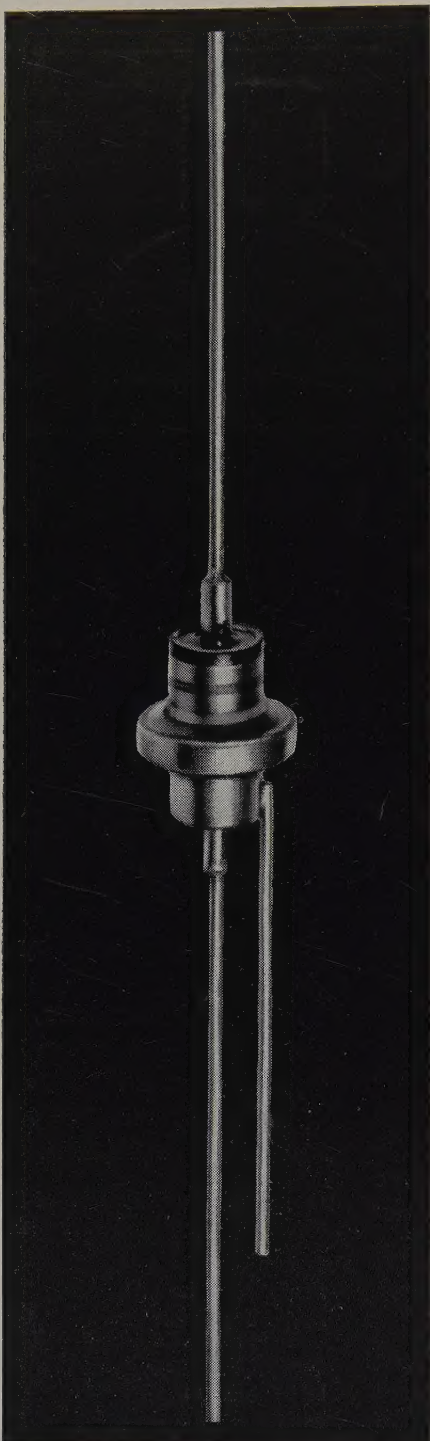

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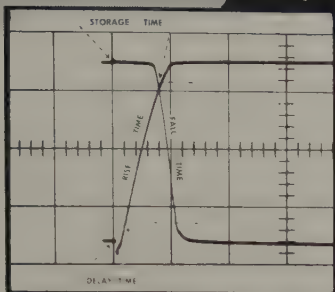

The Type 53/54R Unit can trigger the Oscilloscope sweep either on the start of the test pulse only, or on both the start and finish to display delay, rise, storage, and fall times simultaneously.

The Type 53/54R Unit and your Tektronix Oscilloscope with the Plug-In Feature equip you to measure transistor delay, rise, storage, and fall times. No other equipment is needed. Just plug in the Type 53/54R Unit and you're ready to go.

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Amplitude—0.02 v to 10 v, continuously adjustable, across 50 ohms. Eight calibrated steps—0.05, 0.1, 0.2, 0.5, 1, 2, 5, and 10 v.

Bias Supply
−0.5 v to +0.5 v and −5 v to +5 v, continuously variable. Current Capability—±100 ma.

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Price—$300 f.o.b. factory

High-frequency characteristics of a transistor under five different conditions of drive. In each pair, the photograph at left shows delay time and rise time, the start of the driving pulse coinciding with the 2-cm graticule line. The second photograph of each pair shows storage time and fall time, the end of the pulse coinciding with the 2-cm line. The Type 53/54R Unit plugged into a Tektronix Type 543 Oscilloscope — 3.5-v collector supply, 500-ohm collector load, 2-ma/div vertical calibration, 0.5-μsec/div sweep rate. Driving conditions at left of each pair.

Low-frequency characteristics of the same transistor under driving conditions paralleling those of the first three pairs at left. Family of curves photographed on a Tektronix Type 575 Transistor-Curve Tracer—0.5-v/div horizontal calibration, 1-ma/div vertical calibration, 500-ohm load line. Driving conditions at right of each photograph.

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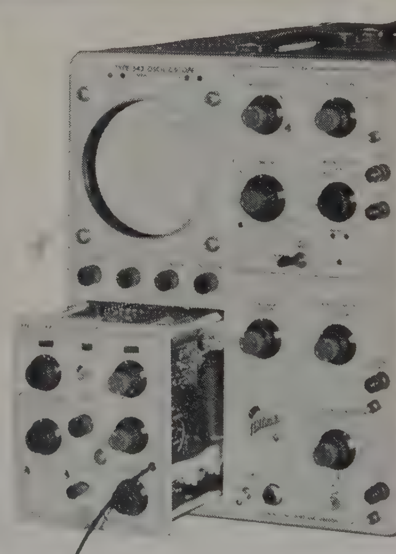
Drive voltage 2 v through 1 kilohm.
Drive voltage 0.5 v through 50 ohms.
Class A drive: 0.05 v through 50 ohms.
Class A drive: 0.1 v through 1 kilohm.

Drive voltage 0.2 v/step through 20 kilohms.
Drive voltage: 0.05 v/step through 1 kilohm.
Drive voltage: 0.02 v/step through 50 ohms.



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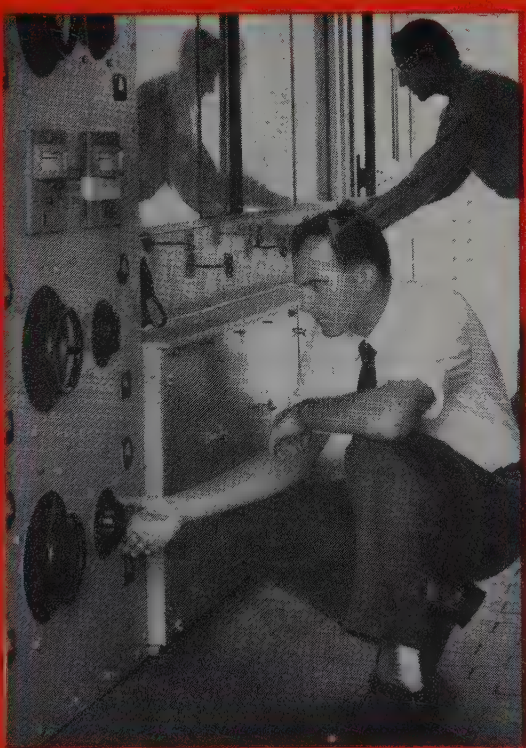

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Optimum Noise Performance of Transistor Input Circuits‡

R. D. MIDDLEBROOK*

Some results are presented for optimum noise performance of transistor input stages when fed from resistive or reactive sources. Standard theory has shown that a common-emitter transistor fed from a resistive source presents a minimum noise figure F_m when the source resistance has a certain value R_{gm} in the order of 1k. In this article, expressions are developed for minimum noise figure and optimum source resistance in the presence of base bias resistors, emitter degeneration resistance, and various kinds of feedback. Results are in terms of F_m and R_{gm} only, and do not contain other functions of the transistor internal noise sources. It is shown that the minimum noise figure is never less than F_m but the optimum source resistance can be either greater or less than R_{gm}. In the case of reactive sources, noise figure is meaningless and the quantity of interest is signal-to-noise ratio over the passband. It is shown that for an inductive source, such as a magnetic tape head, there is a maximum signal-to-noise ratio obtainable with an optimum source inductance, and that a Figure of Merit can be assigned to the source which is independent of its inductance. Experimental results presented for both resistive and inductive sources show good agreement with the theoretical predictions.

INTRODUCTION

THE NOISE performance of any electronic circuit, whether measured in terms of noise figure or signal-to-noise ratio, is dependent on two classes of properties: first, the physical sources of noise within the circuit components, and second, the way in which the components are interconnected. This article is concerned with the second of these, and in particular, with the effects on the overall noise performance of various circuit arrangements of transistors and passive elements with given noise properties.

It has been shown by Bargellini and Herscher[1] that a transistor fed from a resistive source exhibits a noise figure F which is a function of the transistor internal parameters and noise sources and of the external signal source resistance R_g. It was also shown that the noise figure exhibits a minimum value F_m when the source resistance has an optimum value R_{gm} in the order of $1k$, and that the values of F_m and R_{gm} are essentially the same whether the transistor is in *CE, CB* or *CC* connection.

It will be shown in the following work that the noise figure of a circuit containing a *CE* transistor and a resistive signal source exhibits a minimum noise figure F_m' for an optimum source resistance R_{gm}' in the presence of bias resistors, emitter degeneration resistors and feedback. Expressions for F_m' and R_{gm}' are presented in terms of F_m and R_{gm} as defined above. It will be shown that F_m' is always equal to or greater than F_m, and that R_{gm}' may be either greater than or less than R_{gm}. However, it is easy to design circuits in which F_m' exceeds F_m by only a small amount.

In many practical applications the signal source feeding a transistor amplifier is not purely resistive. In these circumstances the noise performance of the entire circuit is more conveniently expressed in terms of signal-to-noise ratio at the output rather than in terms of noise figure. Indeed, noise figure becomes meaningless if the signal source is purely reactive, a condition approximated in magnetic tape heads. It is obvious that the noise performance in such cases is intimately connected not only with the properties of the transistor and associated circuitry, but also with the properties of the signal source or transducer.

Since the design of transistor amplifiers to be fed from magnetic tape heads or other inductive sources is of some practical importance, it is of interest to inquire whether an optimum source inductance exists which would maximize the output signal-to-noise ratio of the whole circuit. It will be shown in the following work that under certain conditions an optimum source inductance does in fact exist, and expressions for this quantity and for the maximum attain-

*Electrical Engineering Department, California Institute of Technology, Pasadena, California

‡Presented at the Philadelphia Transistor and Solid State Circuits Conference, February 1958

[1]P. M. Bargellini and M. B. Herscher, "Investigations of noise in audio frequency amplifiers using junction transistors," Proc. IRE., vol. 43, pp. 217-226; February 1955.

signal-to-noise ratio will be given. These expres- are in a convenient form for practical use, since are in terms of quantities easily measurable or ilable from the noise properties of the first-stage sistor, the overall gain versus frequency charac- tic, and certain circuit parameters concerned with biasing arrangements of the first-stage transistor. ill further be shown that a Figure of Merit can scribed to an inductive signal source, to which the al-to-noise ratio of the complete amplifier is pro- ional. Experimental results presented for both re- ve and inductive sources show good agreement the theoretical predictions.

Amplifier Noise Figures with Resistive Sources

he equivalent circuit to be used to represent a y transistor is shown in *Fig. 1*. This representa- is stripped to the bare essentials since the present cern is with the circuit properties of the transistor not with its internal performance. The simpler equivalent circuit of the transistor, the simpler more illuminating will be the desired results, and justification for such simplicity will be found in validity of the results for practical purposes. Thus he tee equivalent circuit of *Fig. 1*, the emitter and e resistances are assumed negligibly small, the col- or resistance negligibly large, and frequencies of rest are assumed to be such that collector capaci- ce and variations of the current gain α may be ored. The internal mechanisms of noise generation here of no interest, and the simplest valid repre- tation of the noise is by means of an emitter noise tage generator v_{ne} and a collector noise current erator i_{nc}. The polarities shown in *Fig. 1* are of rse arbitrary, since ultimately only noise powers of interest. The quantities v_{ne} and i_{nc} are defined *rms* noise voltage and current in 1 *cps* bandwidth, d in the present work are considered to be the same all frequencies; thus "1/f noise" is neglected. How- er, this limitation is not necessary, and the prin- les of most of the calculations described herein are ually valid if this restriction is removed, although complexity of the results is considerably in- eased.

For future purposes, it is convenient to suppose at the emitter noise voltage is due to a fictitious mitter effective noise resistance" R_{ne} defined by $v_{ne}^2 = 4kTR_{ne}$, where k is Boltzmann's constant and T the absolute temperature.

If a noisy transistor is connected as a *CE* amplifier a signal source of internal resistance R_g, and ther- al noise voltage $v_{ng} = (4kTR_g)^{1/2}$ in 1 *cps* band- idth as in *Fig. 1*, it is easily shown that the noise gure F of the circuit is given by

$$F = 1 + \frac{v_{ne}^2 + R_g^2\, i_{nc}^2/\alpha^2}{4kTR_g} \qquad (1)$$

he noise figure is therefore a function of the generator resistance R_g, and exhibits a minimum value F_m when the generator resistance has an optimum value R_{gm}, where

$$R_{gm} = \frac{\alpha v_{ne}}{i_{nc}} \qquad (2)$$

$$F_m = 1 + \frac{2v_{ne}^2}{4kTR_{gm}} = 1 + \frac{2R_{ne}}{R_{gm}} \qquad (3)$$

The above equations may be obtained from the work of Bargellini and Herscher[1] by appropriate simplification.

Figure 2 shows the general form of the variation of the noise figure F as a function of the generator resistance R_g for the circuit of *Fig. 1*. For a low-noise transistor, F_m is of the order of 2.5 (4 *db*) and R_{gm} in the region of 1*k*. These two quantities are readily measured, and from them the parameters v_{ne}, i_{nc}, and R_{ne} can be determined from *Eqs.* (2) and (3). From the applications point of view, the circuit measurements are more appropriate than the internal generators v_{ne} and i_{nc}, and hence in the following work results will be expressed in terms of F_m and R_{gm}.

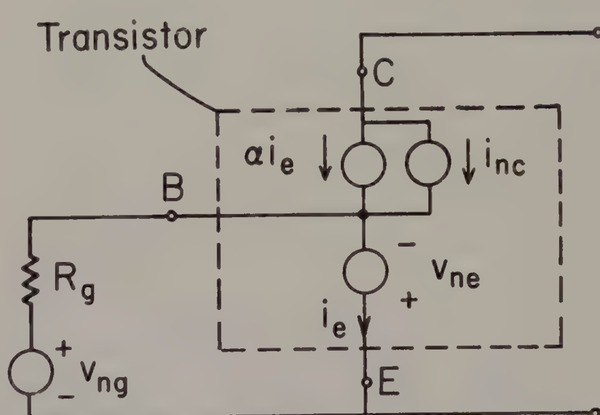

Fig. 1—Simple equivalent of *CE* transistor amplifier fed from resistive source.

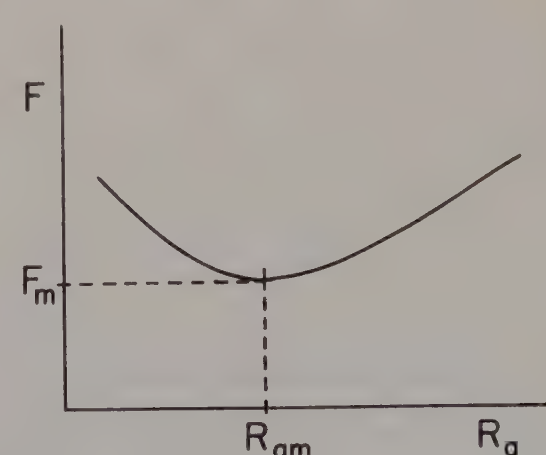

Fig. 2—Noise figure *F* vs. source resistance R_g for the amplifier of *Fig. 1*.

Practical transistor amplifiers are rarely as simple as that shown in *Fig. 1*. It is, therefore, of interest to consider the effects on noise performance of typical associated circuitry. *Fig. 3* shows the equivalent circuit of a generalized transistor amplifier input stage which contains most of the features likely to be encountered in a realistic amplifier: the input signal voltage E_g may arise in a reactive source of impedance $Z_g = R_g + jX_g$ and with thermal noise $v_{ng} = (4kTR_g)^{1/2}$; the resistor R_1 and its thermal noise $v_{n1} = (4kTR_1)^{1/2}$ accounts for any biasing arrangement to the base of the first-stage transistor, such as the usual potential divider; the resistor R_2 and its thermal noise $v_{n2} = (4kTR_2)^{1/2}$ accounts for any emitter degeneration caused by un-bypassed emitter resistance; and the generators U_a, U_b, and U_c account, respectively, for bias resistor bootstrapping, feedback to the base, and feedback to the emitter, all proportional to the complete amplifier output voltage E. It is assumed that all noise sources following the first-stage transistor may be neglected.

Let it first be supposed that the signal source is purely resistive, thus $X_g = 0$. The noise figure F' of the complete amplifier may be computed with greater complexity than difficulty, and is found to show a minimum value F_m' when the source resistance has an optimum value of R_{gm}'. These quantities may be expressed in terms of the corresponding quantities F_m and R_{gm} for the simple *CE* transistor (defined above) as

$$\frac{R_{gm}'}{R_{gm}} = \left[\frac{1 + (R_2/R_{gm})^2 + R_2/R_{ne}}{(1 + R_2/R_1)^2 + (R_{gm}/R_1)^2 + (1 + R_2/R_1)R_{gm}^2/R_1R_{ne})}\right]^{\frac{1}{2}} \quad (4)$$

$$\frac{F_m' - 1}{F_m - 1} = \frac{R_2}{R_{gm}} + R_{gm}\left(1 + \frac{R_2^2}{R_{gm}^2} + \frac{R_2}{R_{ne}}\right)\left(\frac{1}{R_1} + \frac{1}{R_{gm}'}\right) \quad (5)$$

Although interpretation of the above equations is somewhat laborious, one conclusion is immediately obvious: neither R_{gm}' nor F_m' depends on any of the feedback generators U. The importance of this result may be emphasized by stating it in other words: the input impedance and the gain characteristic of the amplifier are strongly dependent on any feedback, but the minimum noise figure attainable and the optimum source resistance to provide it are unaltered by feedback and remain the same as when no feedback is applied.

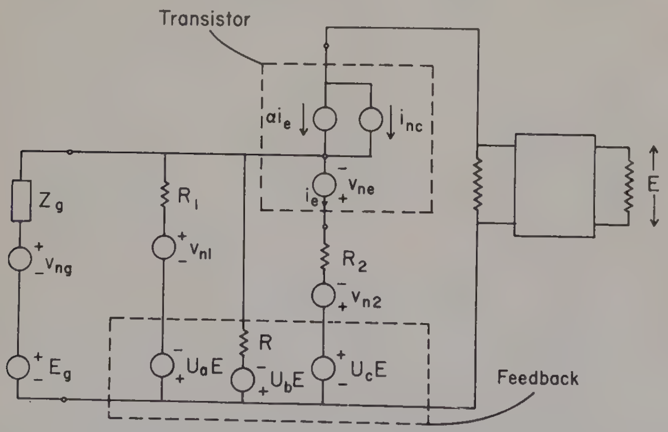

Fig. 3—Generalized transistor amplifier fed from reactive source, including input (base) shunt resistance and emitter degeneration resistance with thermal noise, also feedback generators which are functions of amplifier output voltage.

It is seen from *Eqs.* (4) and (5) that the only elements causing R_{gm}' and F_m' to differ from R_{gm} and F_m are the resistors R_1 and R_2. In order to obtain a clearer understanding of their effects, it is convenient to consider the modifications introduced by R_1 and R_2 separately. If, first, $R_2 = 0$, *Eqs.* (4) and (5) reduce to

$$\frac{R_{gm}}{R_{gm}'} = \left[1 + \frac{R_{gm}^2}{R_1^2}\left(1 + \frac{R_1}{R_{ne}}\right)\right]^{\frac{1}{2}} \quad (6)$$

$$\frac{F_m' - 1}{F_m - 1} = R_{gm}\left(\frac{1}{R_1} + \frac{1}{R_{gm}'}\right) \quad (7)$$

It is seen from the above results that $R_{gm}' \geqslant R_{gm}$ and $F_m' \geqslant F_m$, that is, the presence of R_1 always increases the minimum noise figure and decreases the optimum source resistance necessary to achieve it.

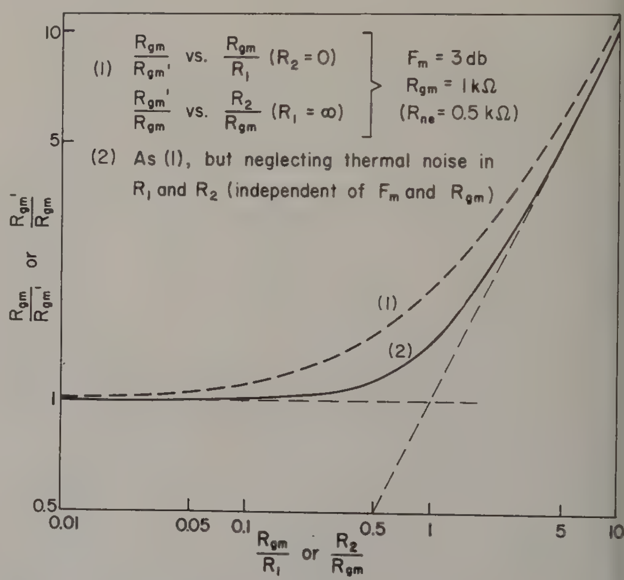

Fig. 4—Optimum source resistance R_{gm}' as a function of R_1 or R_2. Neglect of thermal noise generated in R_1 and R_2 introduces only small error.

If, next, $R_1 = \infty$, *Eqs.* (4) and (5) reduce to

$$\frac{R_{gm}'}{R_{gm}} = \left(1 + \frac{R_2^2}{R_{gm}^2} + \frac{R_2}{R_{ne}}\right)^{\frac{1}{2}} \quad (8)$$

$$\frac{F_m' - 1}{F_m - 1} = \frac{1}{R_{gm}}(R_2 + R_{gm}') \quad (9)$$

from which it is seen that $R_{gm}' \geqslant R_{gm}$ and $F_m' \geqslant F_m$, that is, the presence of R_2 always increases the minimum noise figure and increases the optimum source resistance necessary to achieve it.

The similarity between the pairs of equations (6), (7), and (8), (9) suggests that a single graph with appropriate variables could be drawn for the corresponding equations in each pair. Curve 1 in *Fig. 4* shows *Eq.* (6) or (8) plotted for the special case of a transistor with $F_m = 2$ (3 *db*) and $R_{gm} = 1k$, for which $R_{ne} = 0.5k$ from *Eq.* (3). Curve 1 in *Fig. 5* shows *Eq.* (7) or (9), for the same transistor, plotted to show the excess of F_m' over F_m as a function of R_1 or of R_2.

Equations (6) and (8) may be simplified if the thermal noise generated by R_1 and R_2 is neglected.

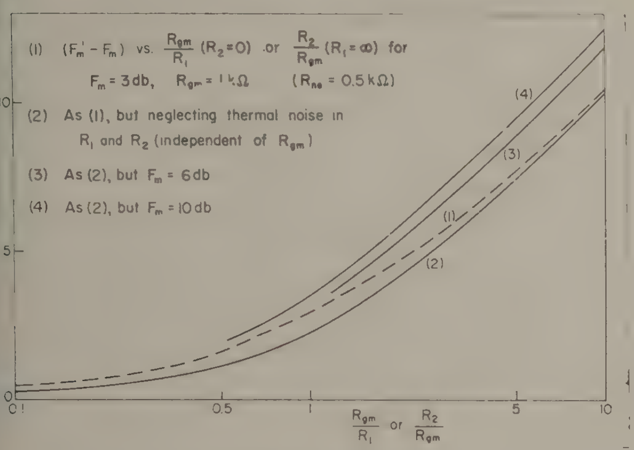

Fig. 5—Increase in minimum noise figure caused by R_1 or R_2. Neglect of thermal noise generated in R_1 and R_2 introduces only small error.

This approximation is equivalent to omitting the terms in R_{ne} in *Eqs.* (6) and (8), and is easily shown to be valid if $R_{ne} >> R_{gm}/2$ or if $F_m >> 2$ (3 *db*) which is the same condition. To indicate the error introduced by this approximation, curves 2 in *Figs.* 4 and 5 show how curves 1 are modified when the terms in R_{ne} are neglected in *Eqs.* (6) and (8). It is seen that the error is greatest when R_{gm}/R_1 or R_2/R_{gm} is equal to 1, and that the maximum error is 30% in R_{gm}/R_1 or R_2/R_{gm}, and 0.7 *db* in $(F_m' - F_m)$. It should be noted that curves 1 and 2 in both *Figs.* 4 and 5 are for $F_m = 2$ (3 *db*) which hardly satisfies the validity condition for the approximation, and even so the error is tolerable. It may be concluded, therefore, that in most practical cases the thermal noise due to R_1 and R_2 may be neglected in computing the noise figure of the circuit, in which case *Eqs.* (6) and (8) reduce to

$$\frac{R_{gm}}{R_{gm}'} = \left(1 + \frac{R_{gm}^2}{R_1^2}\right)^{\frac{1}{2}} \tag{10}$$

for $R_2 = 0$, and

$$\frac{R_{gm}'}{R_{gm}} = \left(1 + \frac{R_2^2}{R_{gm}^2}\right)^{\frac{1}{2}} \tag{11}$$

for $R_1 = \infty$. A further advantage of making the approximation is that curve 2 in *Fig. 4* is now independent of F_m and R_{gm}, and is hence a universal curve

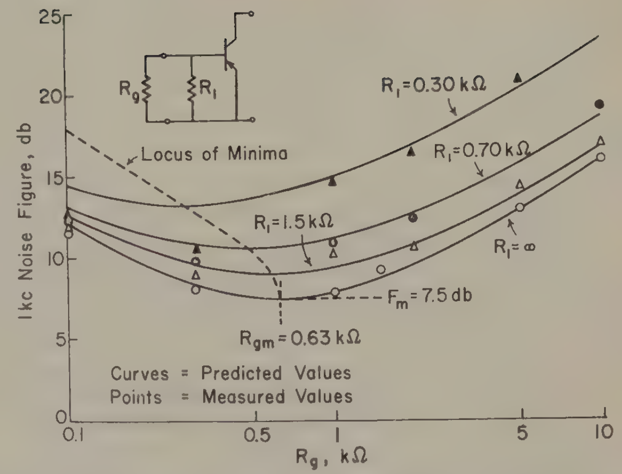

Fig. 6—Comparison between predicted and measured noise figure curves as functions of source resistance, for resistive source and $R_2 = 0$. Thermal noise generated in R_1 was neglected in computing the predicted curves.

for all transistors, and curve 2 in *Fig.* 5 is independent of R_{gm}.

Some further conclusions may be drawn from *Figs.* 4 and 5: if $R_1 >> R_{gm}$ or if $R_2 << R_{gm}$, R_{gm}' is little different from R_{gm}, and F_m' is little greater than F_m. Since R_{gm} is usually of the order of 1*k*, these conditions are usually realized in practice and the minimum noise figure is not much greater than the minimum possible. If $R_1 << R_{gm}$ or if $R_2 >> R_{gm}$, R_{gm}' tends to R_1 or to R_2 as appropriate, and the minimum noise figure is appreciably greater than the minimum possible. Further, as shown in curves 3 and 4 of *Fig.* 5, the greater the value of F_m for the transistor, the greater is the increase above F_m in the noise figure of the complete circuit.

To check the validity of the results described, experimental measurements of the 1 *kc* noise figure were made for various values of R_1 and R_2 and compared with the predicted values. The procedure was as follows. Measurements of the noise figure F of a since *CE* transistor as shown in *Fig. 1* were made as a function of source resistance R_g. These points should satisfy the relation

$$F = F_m + \frac{(F_m - 1)}{2} \frac{(R_g - R_{gm})^2}{R_g R_{gm}} \tag{12}$$

The line shown in *Fig.* 6 (for $R_1 = \infty$) or in *Fig.* 7 (for $R_2 = 0$) is the best fit with the experimental points which also satisfies *Eq.* (12). From this "best fit" line, the values of F_m and R_{gm} for the experimental transistor at the particular operating point chosen were found to be $F_m = 5.62$ (7.5 *db*) and $R_{gm} = 0.63$ *k*.

In the presence of R_1, the noise figure of F' as a function of source resistance R_g should satisfy the relation

$$F' = F_m' + \frac{(F_m' - 1)}{2(1 + R_{gm}'/R_1)} \frac{(R_g - R_{gm}')^2}{R_g R_{gm}'} \tag{13}$$

where F_m' and R_{gm}' are given by *Eqs.* (7) and (10) respectively. *Fig. 6* shows *Eq.* (13) plotted for three values of R_1, and it is seen that the experimental points agree quite well with the predicted curves. It should be noted that thermal noise in R_1 was neglected in computing the curves, and the agreement between the measured and predicted results is further evidence of the validity of the approximation.

In the presence of R_2, the noise figure F' as a function of source resistance R_g should satisfy the relation

$$F' = F_m' + \frac{(F_m' - 1)}{2(1 + R_2/R_{gm}')} \frac{(R_g - R_{gm}')^2}{R_g R_{gm}'} \qquad (14)$$

where F_m' and R_{gm}' are given by *Eqs.* (9) and (11) respectively. *Fig. 7* shows *Eq.* (14) plotted for two values of R_2, and again the agreement between measured and predicted results is good even though thermal noise in R_2 is neglected.

Amplifier Signal-to-Noise Ratios with Reactive Sources

If the signal source impedance contains a reactive component, the spot noise figure of the complete amplifier will vary with frequency. Indeed, if the source is purely reactive, noise figure becomes meaningless. In such cases a more useful measure of noise performance is the signal-to-noise ratio S_0 at the amplifier output. More precisely, S_0 may be defined as the ratio of the signal power in the load to the total noise power in the load. In general, the signal power in the load will depend on the chosen frequency f_0, the source voltage at f_0, and the overall amplifier gain at f_0. The total noise power in the load will depend on the noise properties of the first-stage transistor and associated circuit elements, any noise from the signal source such as its own resistive thermal noise and noise brought into the system along with the signal, and on the overall gain versus frequency response of the complete amplifier.

The equivalent circuit of the generalized amplifier shown in *Fig. 3* will again provide a suitable foundation for discussion, except that the complex character of the source impedance $Z_g = R_g + jX_g$ will be retained, and in accordance with the results of the previous section the thermal noise generators v_{n1} and v_{n2} will be omitted. An input transformer may also be included in which case E_g, v_{ng}, and Z_g are source parameters referred to the secondary. The output signal-to-noise ratio S_0 at a frequency f_0 may be shown to be

$$S_0 = \frac{\left(\dfrac{2E_{g0}^2}{4kTR_{gm}(F_m - 1)}\right)}{\displaystyle\int_0^\infty \left[\frac{R_g}{R_{ne}} + \left|1 + \frac{Z_g}{R_1}\right|^2 + \frac{1}{R_{gm}^2}\left|Z_g + R_2\left(1 + \frac{Z_g}{R_1}\right)\right|^2\right]\left|\frac{G(f)}{G(f_0)}\right|^2 df} \qquad (15)$$

where E_{g0} is the open-circuit source voltage at frequency f_0, $G(f) = E/E_g$ is the overall voltage gain, and R_{gm}, F_m, and R_{ne} are the noise parameters of the first-stage transistor as previously defined. It is assumed in the above result that there is no noise in the signal source other than that due to its internal resistance R_g, and, as mentioned earlier, that the transistor noise generators v_{ne} and i_{nc} are independent of frequency. If desired, $1/f$ frequency dependence of one or both of these generators could be introduced with considerably greater complexity in the result.

It is to be noted from the above result that the output signal-to-noise ratio is independent of the amplifier input impedance and of any feedback except insofar as these parameters influence the gain characteristic $G(f)/G(f_0)$.

A special case of considerable practical interest occurs when the signal source is essentially a pure inductance, that is, $R_g \to 0$ and $X_g \to 2\pi f L_g$. A typical source of this type would be a magnetic tape reproduce head or a magnetic phonograph pickup. Under this condition, *Eq.* (15) may be written

$$S_0 = \frac{\left(\dfrac{2M}{F_m - 1}\right) 2\pi L_g R_{gm}}{R_{gm}^2 C_1^2 A_1^2 + (2\pi L_g)^2 C_2^2 A_2^2} \qquad (16)$$

in which M is a "source parameter" defined as

$$M = \frac{E_{g0}^2}{8\pi k T f_0^2 L_g} \qquad (17)$$

A_1 and A_2 are "gain parameters" defined by

$$A_1 = \frac{1}{f_0}\left(\int_0^\infty \left|\frac{G(f)}{G(f_0)}\right|^2 df\right)^{\frac{1}{2}} \qquad (18)$$

$$A_2 = \frac{1}{f_0}\left(\int_0^\infty \left|\frac{G(f)}{G(f_0)}\right|^2 f^2 df\right)^{\frac{1}{2}} \qquad (19)$$

and C_1 and C_2 are "circuit parameters" defined by

$$C_1 = \left(1 + \frac{R_2^2}{R_{gm}^2}\right)^{\frac{1}{2}} \qquad (20)$$

$$C_2 = \left[\left(1 + \frac{R_2}{R_1}\right)^2 + \frac{R_{gm}^2}{R_1^2}\right]^{\frac{1}{2}} \qquad (21)$$

Some properties of the "source parameter" M are of interest. Consider a magnetic tape head containing N turns of wire of negligible resistance. If the head is stimulated by a tape recorded with constant flux amplitude at all frequencies $\phi = \Phi \sin 2\pi ft$, then the open-circuit voltage of the head will be proportional to the frequency and to the number of turns:

$$E_g \sim N\frac{d\phi}{dt} \sim Nf \qquad (22)$$

However, the inductance of the head is proportional to the square of the number of turns:

$$L_g \sim N^2 \qquad (23)$$

The above relations assume no leakage flux and that the head gap is small compared to the recorded wavelength. It follows from *Eqs.* (22) and (23) that the quantity E_g^2/f^2L_g is independent of frequency and the number of turns, and hence of the inductance, if the tape is recorded with constant flux amplitude. Similarly, for a phonograph pickup the same remarks apply if the disk recording characteristic is constant amplitude at all frequencies. Even if the recording characteristic is not constant amplitude, E_g^2/f^2L is still independent of the inductance though not of frequency.

It follows, therefore, that the "source parameter" may be rewritten

$$M = \frac{E_g^2}{8\pi kTf^2L_g} \qquad (24)$$

and may be called a Figure of Merit for the source which is independent of its inductance and also, in certain circumstances, of frequency. A definition of the Figure of Merit in physical terms may be expressed as follows:

$$M = \frac{2(\text{max. available signal energy in 1 cycle})}{\text{thermal energy in 1 cycle}}$$

The source Figure of Merit is a dimensionless number which may for convenience be expressed in *db*.

Attention may now be returned to *Eq.* (16). The output signal-to-noise ratio S_0 is seen to be a function of the source inductance L_g, and since it has been shown that M is independent of L_g it follows that S_0 exhibits a maximum value S_{om} when the source inductance has an optimum value L_{gm}, where, from *Eq.* (16)

$$L_{gm} = \frac{R_{gm}}{2\pi}\frac{A_1C_1}{A_2C_2} \qquad (25)$$

$$S_{0m} = \frac{M}{(F_m - 1)A_1A_2C_1C_2} \qquad (26)$$

The optimum source inductance L_{gm} is, of course, independent of the frequency f_0 at which S_0 is determined, while S_0 is not, in general, independent of f_0.

It has thus been shown that an optimum source inductance exists for which a maximum output signal-to-noise ratio is realized, and expressions for these two quantities have been given in terms of a source Figure of Merit, the first-stage transistor noise parameters F_m and R_{gm}, amplifier overall gain parameters, and circuit parameters containing only the resistors R_1 and R_2 shown in *Fig.* 3. The results are easily applied to practical design problems to determine the maximum attainable signal-to-noise ratio

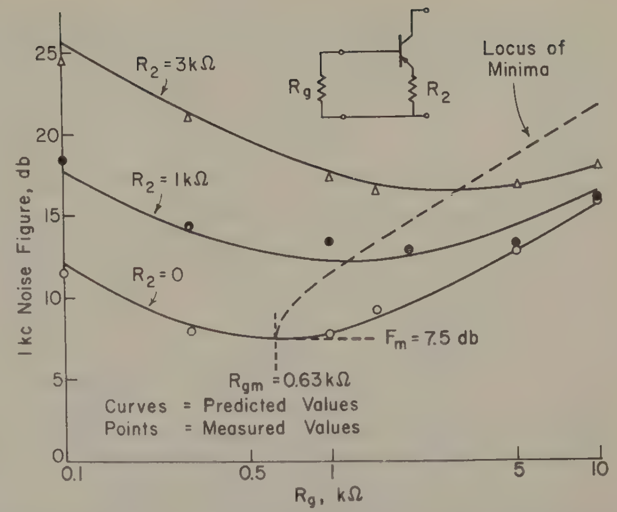

Fig. 7—Comparison between predicted and measured noise figure curves as functions of source resistance, for resistive source and $R_1 = \infty$. Thermal noise generated in R_2 was neglected in computing the predicted curves.

and the required source inductance. For a given source, it is of course usually more convenient to match the existing source inductance to the optimum value by a transformer than to redesign the transducer.

Some typical figures will help to give insight into the magnitudes involved. Suppose a transistor amplifier is to be designed to provide constant output at all frequencies between $f_1 = 50$ *cps* and $f_2 = 10$ *kc* from a magnetic tape recording. It is desired to find the maximum attainable signal-to-noise ratio and the optimum source inductance given that the first stage transistor has $F_m = 4$ (6 *db*), $R_{gm} = 1k$, and that the tape head has an inductance of 3 *mh* and provides an output of 0.6 *mv* at 1 *kc*.

Insertion of the given figures for the tape head into *Eq.* (24) leads to a value for the Figure of Merit of $M = 1.2 \times 10^9$ (91 *db*). It remains only to find the "circuit parameters" and the "gain parameters." To take a case worse than would probably occur in practice, suppose that in the circuit of *Fig.* 3 $R_1 = 5k$ and $R_2 = 1k$. Use of *Eqs.* (20) and (21) leads to $C_1 = 1.41$, $C_2 = 1.22$ (note that $C_1 = C_2 = 1$ if $R_1 = \infty$ and $R_2 = 0$). To find the "gain parameters," the gain characteristic must be determined. Since the tape recording is constant amplitude, the open-circuit output voltage of the head will fall as the frequency rises at 6 *db* per octave, and since an amplifier output voltage constant with frequency is required, the inverse characteristic must be provided in the amplifier. Hence $|G(f)/G(f_0)|^2 = (f_0/f)^2$, and if for simplicity it is supposed that sharp cutoff occurs at a low frequency f_1 and a high frequency f_2, use of *Eqs.* (18) and (19) leads to $A_1 = 1/f_1^{1/2}$, $A_2 = f_2^{1/2}$. With $f_1 = 50$ *cps* and $f_2 = 10$ *kc* as given, use of *Eqs.* (25) and (26) leads to $L_{gm} = 260$ *mh*, $S_{om} = 72$ *db*, where the signal-to-noise ratio is in this case independent of signal frequency chosen because of the output characteristic specified. Thus an output signal-to-noise

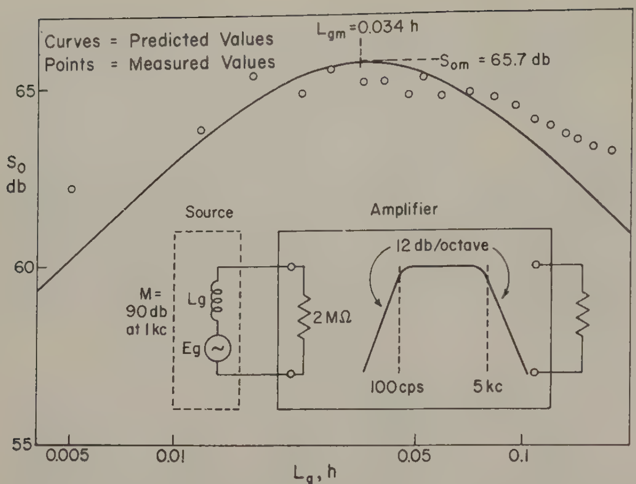

Fig. 8—Comparison between predicted and measured signal-to-noise ratio as functions of source inductance. Source Figure of Merit taken as $M = 10^9$ (90 *db*).

ratio of 72 *db* can be realized if the number of turns on the tape head is increased to make its inductance 260 *mh*, or alternatively if a step-up input transformer of turns ratio $(260/3)^{1/2} = 9.3$ is used with the given head.

Experimental Results for Inductive Source

An experiment was performed to verify the theoretical prediction that a maximum signal-to-noise ratio exists for an optimum value of source inductance. Since the source inductance was to be varied, a high input impedance to the transistor amplifier was desired so that the gain function $|G(f)/G(f_0)|^2$ should not change with source inductance. The signal-to-noise ratio S_0 at 1 *kc* as a function of source inductance L_g was determined theoretically and experimentally as follows.

A transistor feedback amplifier was constructed with a constant voltage gain between low and high frequency roll-offs of 12 *db* per octave, the break frequencies being approximately 100 *cps* and 5 *kc*. The first stage of the amplifier contained the same transistor, at the same operating point, whose noise characteristics are shown in *Figs.* 6 and 7. The input impedance was not less than 2 megohms throughout the passband. The resistor R_1 was negligibly large, and R_2 was 1*k*. Since $R_{gm} = 0.63k$ and $F_m = 5.6$ (7.5 *db*), the circuit parameters can be found from *Eqs.* (20) and (21) to be $C_1 = 1.88$, $C_2 = 1$. By use of *Eqs.* (18) and (19) and straight-line approximations to the gain characteristic, the gain parameters may be found analytically to be $A_1 \approx 0.082\ (cps)^{-1/2}$, $A_2 \approx 410\ (cps)^{1/2}$ at $f_0 = 1$ *kc*. Numerical integration of the measured gain characteristic led to more accurate values of $A_1 = 0.076\ (cps)^{-1/2}$, $A_2 = 420\ (cps)^{1/2}$, and it may be noted that the approximate analytical values are quite adequate for practical applications. If an inductive signal source with a Figure of Merit $M = 10^9$ (90 *db*) at 1 *kc* is assumed, *Eqs.* (25) and (26) predict that the amplifier should exhibit a maximum signal-to-noise ratio $S_{0m} = 65.7$ *db* when the source inductance has an optimum value $L_{gm} = 0.0343$ *h*.

Experimental measurements of output signal-to-noise ratio were made on the amplifier with a true *rms* voltmeter. The signal source was a simulated magnetic tape head consisting of a variable inductance L_g in series with a 1 *kc* voltage E_g from an oscillator whose magnitude was adjusted to maintain a constant Figure of Merit of 90 *db*: thus, from *Eq.* (24), $E_g^2/L_g = 1.03 \times 10^{-4}\ v^2/h$. The results are shown in *Fig. 8*, in which the solid curve is the predicted 1 *kc* signal-to-noise ratio as a function of source inductance with $S_{0m} = 65.7$ *db* and $L_{gm} = 0.0343$ *h*. The points are the measured values obtained with the dummy inductive source. The agreement between predicted and measured values is quite close.

Conclusions

The noise performance of transistor amplifier circuits fed from resistive and reactive sources has been discussed.

For resistive sources, it has been shown that a minimum noise figure exists for an optimum source resistance, that these quantities are independent of any feedback, but dependent on equivalent input shunt resistance and on equivalent emitter degeneration resistance in the first stage *CE* transistor. The presence of these two resistances increases the minimum noise figure, but the degradation is only slight with resistance values easily achieved in practice.

For inductive sources, such as a magnetic tape head or a magnetic phonograph pickup, it has been shown that a Figure of Merit can be ascribed to the source which is independent of its inductance. It has further been shown that a maximum signal-to-noise ratio is attainable at the amplifier output for an optimum source inductance. Expressions for these two quantities have been given in terms of the source Figure of Merit, first-stage transistor noise properties, circuit parameters and gain parameters. Typical figures and experimental results in close agreement with theory have been presented.

It is to be emphasized that the criteria for best noise performance, whether the source is resistive or reactive, are in no way connected with the criteria for maximum power transfer from the source.

ACKNOWLEDGMENTS

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"Trisistor" — An Alloyed Junction Trigger Transistor

Dr. SERGE PAKSWER* ADOLPH WOLSKI*

Thyratron-like characteristics are observed in alloyed-junction transistors when alloying pellets of a modified composition are used, containing both suitable donor and acceptor elements. In a reverse-biased grounded-emitter circuit, very fast (10-20 millimicroseconds for small units, 200 millimicroseconds for large units) switching from a low-current "off" state to a high-current low-voltage (~ 1 V) "on" state can be obtained, the triggering voltage being a function of the base input current. Due to some peculiarities of the grounded base characteristics, particularly simple relaxation oscillator circuits can be developed for these units.

THERE IS AT present a steadily increasing interest in switching devices for use in computers, sweeps, ıdustrial controls, etc. The operation of switching evices is based on the presence of two distinct states ı-on-off, high-low, conducting-nonconducting states, oth sometimes connected by a transition region such s a region of negative resistance. Such switching evices can be of the two-terminal type, or they can ave a third terminal which serves as a control or rigger electrode.

This paper will describe the construction of a simple 3-terminal unit consisting of a germanium base lab and two alloyed junctions respectively for the mitter and collector. This unit has been obtained by nodifying the composition of the alloying pellet to give the unit properties similar to those of a point contact or a thyratron transistor, namely, a diode reverse current changing with voltage and an α greater than 1; at the same time the junction conserves a satisfactory hole (or electron) injection efficiency.

The materials used for both pellets (emitter and collector) can be modified to give a set of switching characteristics, or only one of the pellet materials can be modified to give a different set of switching characteristics. Consequently, there are two different units with their respective switching properties.

Operation of the Unit

When the collector and/or emitter are made of the modified materials, they have diode characteristics similar to those shown in either *Fig. 1a* or *Fig. 1b* which depict a discontinuity in the reverse diode characteristics.

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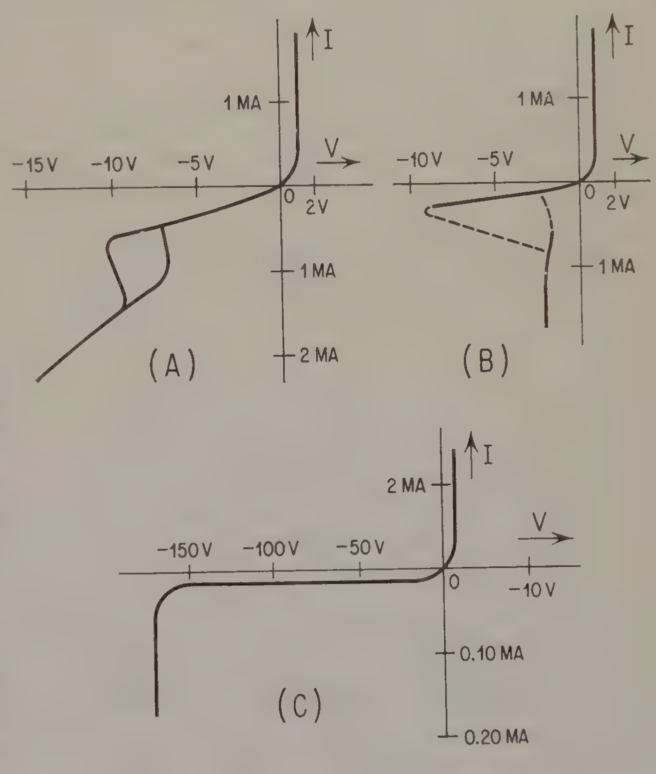

Fig. 1. Diode curves. (A) and (B) show diode curves of pellets made with modified materials. (C) shows conventional diode characteristics for p-n junctions.

The voltage-current characteristics between the emitter and the collector are shown in *Fig. 2*.

When one of the pellets is made of the modified material and the other pellet is a conventional *p-n* alloy junction, the modified pellet will have a diode characteristic as previously described and the other pellet will have a conventional diode characteristic as shown in *Fig. 1c*. The *V-I* characteristic between

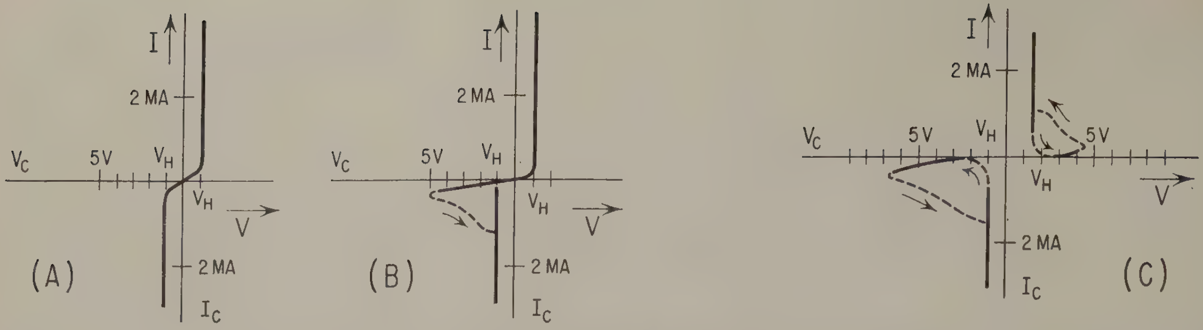

Fig. 2. Breakdown between two modified pellets with base open. (A) breakdown, (B) and (C) variations of switching breakdown.

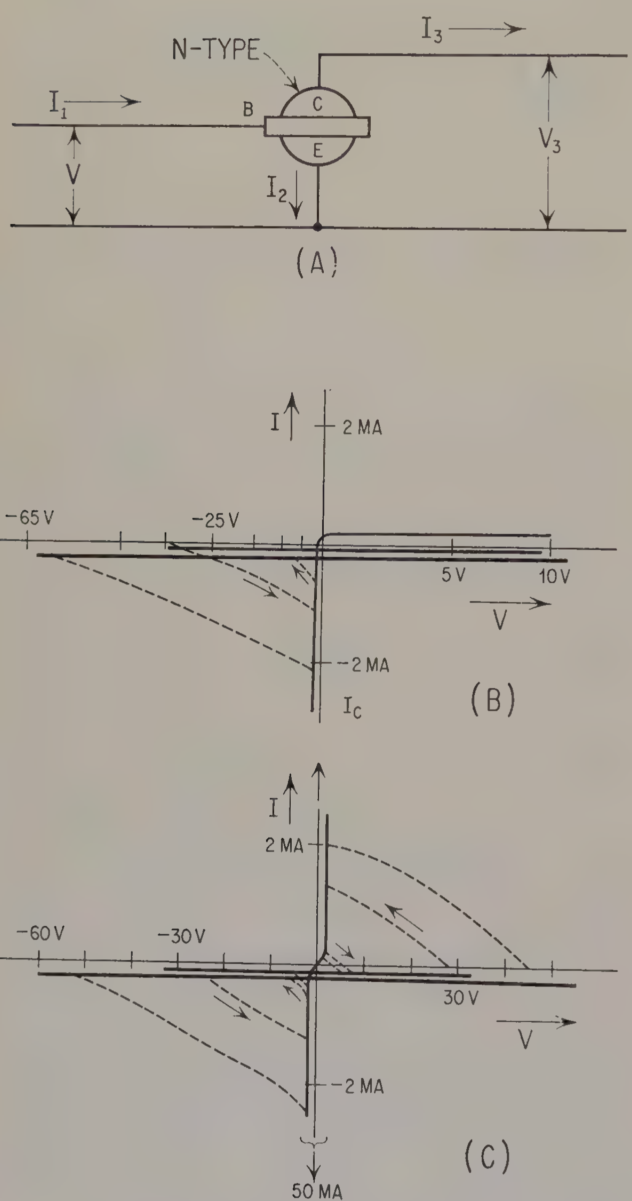

Fig. 4. Operation of the alloyed junction thyratron transistor in grounded emitter circuits. (A) schematic of designations, (B) asymmetric, (C) symmetric units. Typical values for small units:
$I_1 = 0.5$ *mA*; V_{3s} (trigger) 30 *V*; $I_1 = 1$ *mA*; V_{3s} (trigger) 50-60 *V*; I_3 ("on" current) for small units ~50 *mA*; for large units ~ *1A*.

these two pellets is shown in *Fig. 3a* or *b*. From all of these curves, it can be seen that a breakdown exists between the two pellets for very low voltage.

The voltage at which breakdown occurs between the two pellets can be controlled by the use of the base contact of the unit as shown in the schematic diagram of *Fig. 4*. When the base bias I_1 is such that the emitter is reverse biased, the *V-I* characteristic for a unit which has been made with one modified and one conventional pellet is shown in *Fig. 4b*.

The operation of a unit constructed with only the collector pellet *C* made of the modified material can be explained as follows: If the base connection is open, then the emitter *E* is forward biased with respect to collector *C* (positive for a *p-n-p* unit). Because the unit has a section in which rapid multiplication of the carriers takes place, there is a breakdown at $V_H \approx 1$ *V* as shown in *Figs. 3a* or *3b*. The opportunity for multiplication is provided by a feedback loop which transfers the carriers from the collector *C* to the emitter *E* where the carriers are reinjected.

If a positive bias is applied to the base *B*, for example, by connecting *B* to a constant-current generator, both the emitter and the collector are biased in the reverse direction and no carriers can be injected at *E* and multiplied at C. The current I_1 is split into two currents I_2 and I_3. If V_3 is increased, making the collector pellet more negative, I_3 will increase and I_2 will decrease. The amount of increase in I_3 will depend on the slopes of the diode characteristics in the emitter and the collector junctions. As I_2 decreases, V_1 will also decrease. In the neighborhood of $V_1 \approx 0$, the emitter junction becomes biased in the forward direction, as if the base were open; injection starts and multiplication occurs at the collector. The multiplied current is fed back through an external circuit to the emitter where it appears as a counter current to I_2, thus driving the emitter junction more positive. As I_1 is increased, the switching, due to a change from reverse to forward conduction at the emitter, is delayed and the voltage V_3 has to be increased to obtain switching. Thus the base acts like the grid in a grid-controlled gas tube. The switching operation described above can be seen in *Fig. 4b*.

The operation of the unit with two modified pellets is essentially the same as explained above but with some additions. Either the collector or the emitter can be biased to inject holes. Consequently, for a circuit configuration as shown in *Fig. 4a,* there are two switching points for one bias value, as can be seen in *Fig. 4c.*

There are several observations which are pertinent to the transition between the "off" state and the "on" state.

(a) The voltage V_{ss} (at which switching occurs) is a function of the split-up of the bias current I_1, namely, I_2 and I_3.

(b) The switching speed from the "off" state to the "on" state is very great. Switching speeds as high as 1 x 10^{-8} seconds were observed in the units. The switching speed will be further discussed in a later section.

(c) If V_s and I_1 are so adjusted that the units are close to the switching point, illumination of the unit will cause switching to the "on" state. The "off" state will be reestablished as soon as the illumination is removed. It was observed that, for a given I_1, illumination decreases the V_{ss} necessary for switching in proportion to the light intensity.

(d) For a given set of conditions (V_s, I_1), a very small increment of V_s is required to switch the unit from the "off" to the "on" state.

A further interesting set of conditions is obtained when the units are operated in a common-base circuit with the polarities normally applied to a *p-n-p* transistor as shown in *Fig. 5a.* Plotting again the collector voltage V_c vs the collector current I_c for different values of I_e, it can be seen (*Fig. 5b*) that for $I_e = 0$ there is a discontinuity in the reverse diode current as shown in *Fig. 1.* As the emitter current is increased, the discontinuity becomes more enhanced and the curves split in two sections corresponding to an "off" and an "on" condition. The "on" curves "*b*" occur as the voltage V_c is increasing and changes to the "off" curves "*a*" when a certain critical voltage V_c is exceeded. Reversely, if the voltage V_c is now decreased, the unit remains in the "off" state and goes into the "on" state "*b*" when the voltage drops back below the critical value.

Measurements show that at low values of V_c (to the right of the discontinuity), $\alpha < 1$. Beyond the discontinuity $\alpha > 1$, approximately 2 to 5.

Preparation of the Units

We have found that devices of this type require that one or both pellets contain a mixture of donor and acceptor elements. We have also found that excellent results are obtained with devices using *n*-type germanium as the base and pellets containing gallium as an acceptor and antimony as a donor. Since gallium-antimony mixtures present difficulties in the alloying process, these two elements are preferably incorporated in a carrier such as indium or tin (or a mixture of both). We have noticed that when indium-antimony mixtures alone (without gallium) were used, the resulting diode curves were ohmic or *n*-type even with very small (0.13%) amounts of antimony included. When In-Ga-As mixtures were used, the reverse resistance of the junctions was small and higher base currents I_1 were required to trigger

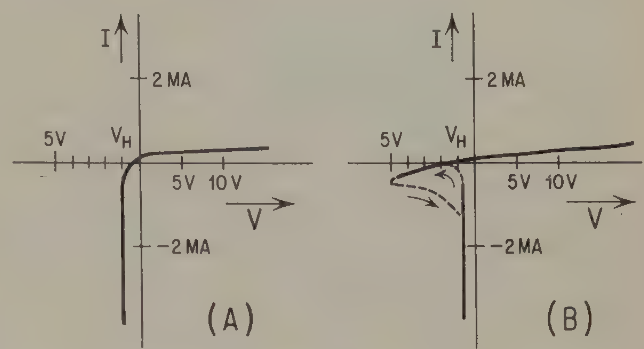

Fig. 3. Breakdown between emitter and collector pellets with base open. (A) breakdown between a modified pellet and a conventional pellet; the modified pellet is made negative; (B) same as (A) only with a switching breakdown.

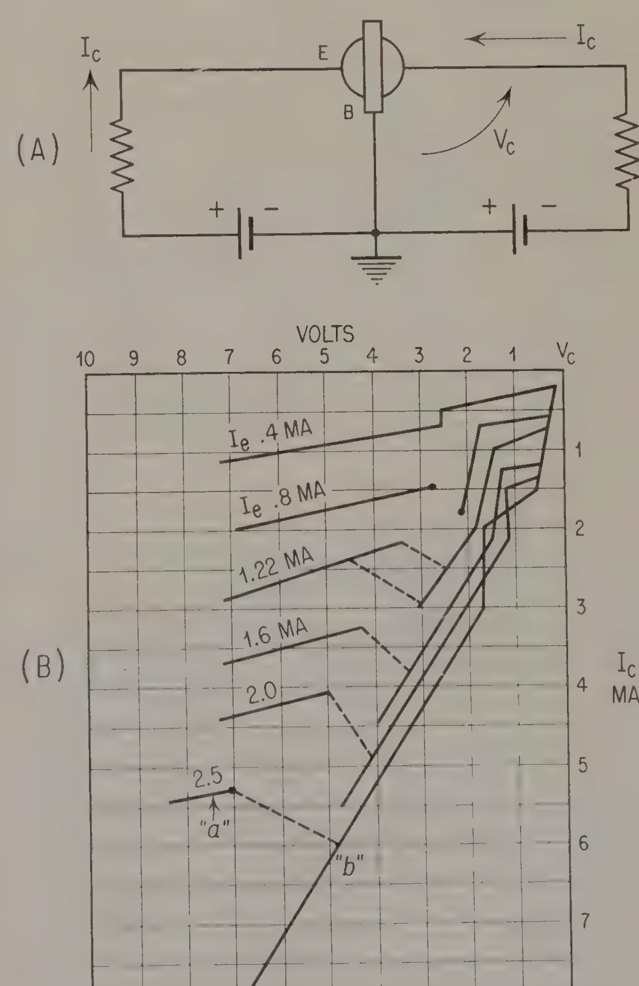

Fig. 5. Operation of alloy junction thyratron transistor in grounded base circuit. (A) circuit diagram, (B) experimental curves.

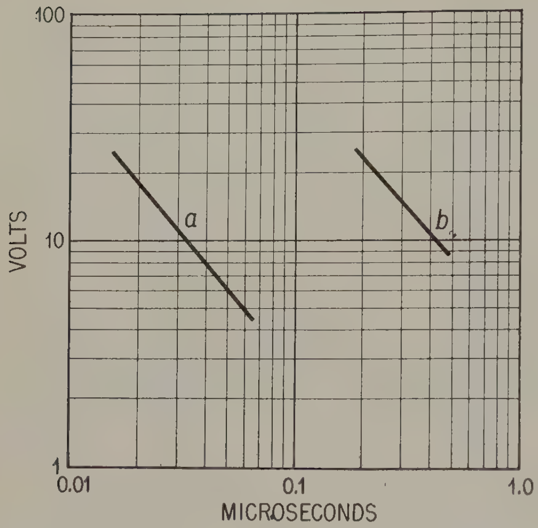

Fig. 6. Representative curves of V_{3s} vs switching time. Curve *a*—"small" unit; curve *b*—"large" unit.

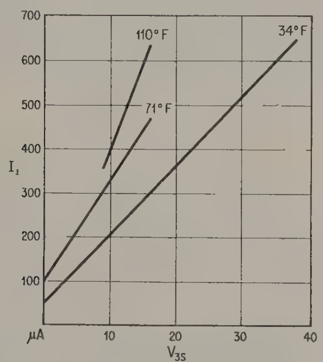

Fig. 7. V_{3s} *vs* I curves *for different temperature* (unit #84)

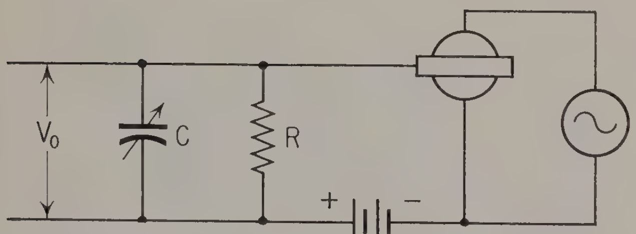

Fig. 9. Three-terminal synchronized oscillator.

the device than in the case of junctions made with pellets containing an equal amount of antimony in place of the arsenic. It can be seen that for units made on an n-type germanium base, the segregation coefficient of the acceptor should be larger than that of the donor.

The devices were made in two sizes using n-type germaninum varying from 7 to 40 ohm-cm. The smaller size wafer was 0.075″ wide, 0.075″ long and from 0.0015″ to 0.004″ thick. The pellets of modified material in this case were cylindrical in shape, 0.015″ in diameter and 0.010″ thick. For the larger size we used wafers 0.250″ x 0.250″ x 0.010″ and the pellets were 0.156″ in diameter and 0.020″ thick. The ohmic contact to the germanium comprised a tin-clad nickel base tab.

Switching Speed

In *Fig. 6* are shown switching times of the units, kindly determined for us by Mr. Jean Isabeau of Zenith Radio Corporation. Curve "*a*" represents the switching time of a "small" unit, curve "*b*" the switching time of a "large" unit. It can be seen that the switching time decreases with increasing voltage V_{3s}.

Temperature Dependence

In *Fig. 7* are shown some curves of V_{3s} against I_1 taken at different temperatures. It can be seen that at higher temperatures a larger base current is required to obtain the same V_{3s}.

Circuit Applications

The thyratron type characteristics of a three-terminal modified junction transistor are desirable in many circuit applications. The discontinuity in the reverse-bias characteristics of a diode modified junction allows simple circuitry. The following examples

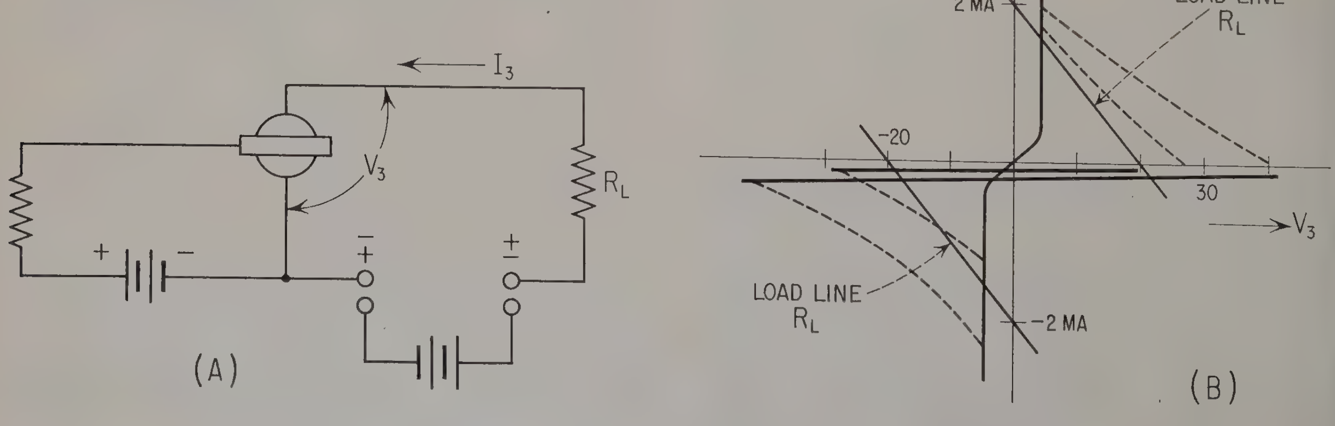

Fig. 11. Trigger type circuit. (A) circuit diagram. (B) load lines.

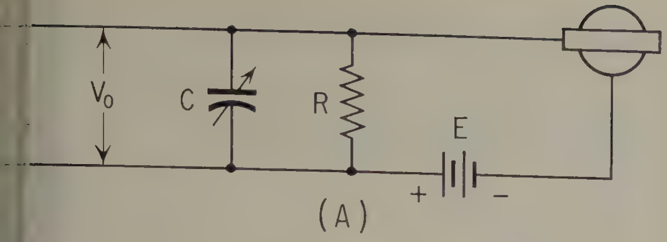

Fig. 8. **Two-terminal relaxation oscillator. (A) circuit diagram, (B) wave shapes.**

show the use of the modified-junction units in various circuit applications.

Utilizing the discontinuity in the reverse-bias characteristics of a modified junction, a simple two-terminal oscillator can be constructed as shown in *Fig. 8.* As the time constant of the *R-C* network is varied, the frequency of oscillation varies. A second junction (modified or conventional) can be added to the unit in *Fig. 8,* as shown in *Fig. 9.* A synchronization frequency can be added to this third terminal to change the free running oscillator into a synchronized oscillator.

A capacitance can also be added between the third terminal and the common connection to form a relaxation oscillator as shown in *Fig. 10.*

The thyratron characteristics of the three-terminal device can be used in the application of trigger circuits. Monostable, astable, and bistable circuits can be constructed using a minimum number of components. By adjusting the load R_L in *Fig. 11,* either the monostable, astable, or bistable conditions can be established.

Utilizing the symmetrical switching characteristics, switching can occur for either positive or negative bias polarities or for pulses across the two modified pellets.

Units encapsulated in glass envelopes can be used for light sensitive switches, since the switching point V_{ss} is proportional to the intensity of light impinging on the semiconductor surface.

The circuits illustrated above were presented only to show the simplicity of circuit design; many other circuit applications are possible utilizing the switching characteristics of these devices.

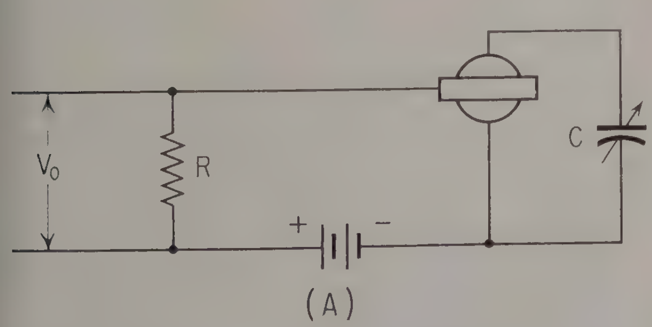

Fig. 10. Three-terminal relaxation oscillator. (A) circuit diagram, (B) wave shapes.

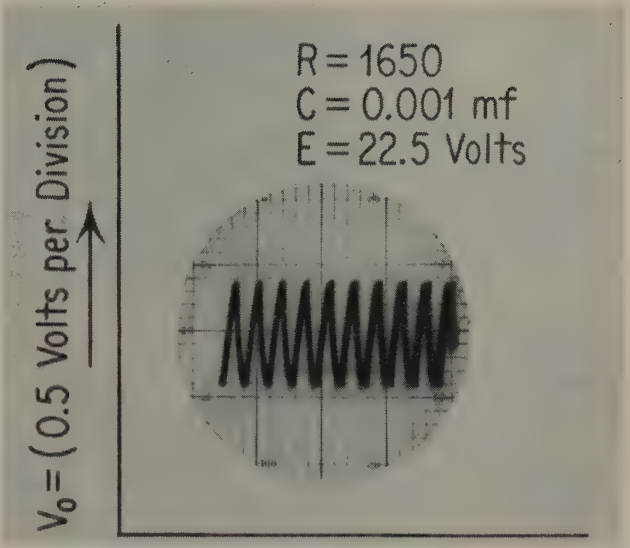

Fig. 8B. 0.1 Msec per pip.

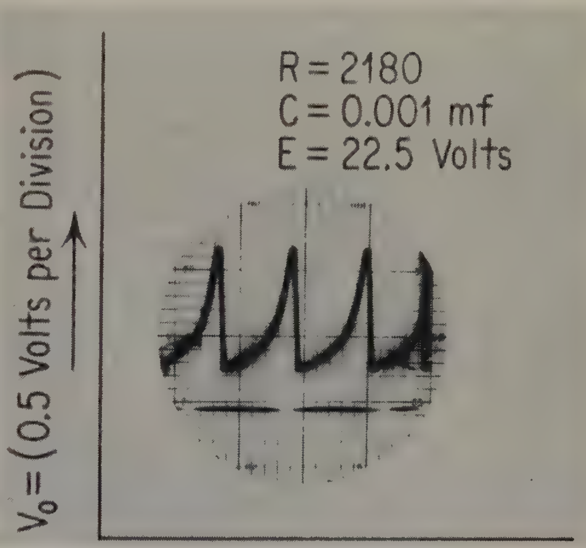

Fig. 10C. 0.1 μsec per pip.

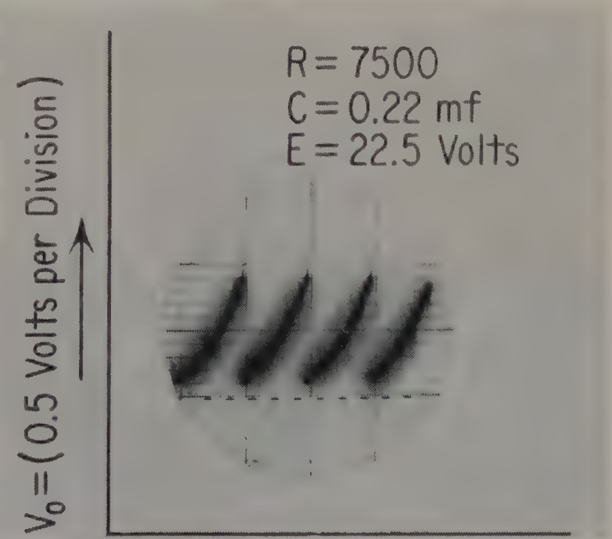

Fig. 10B. 0.1 Msec per pip.

Ten Megapulse Transistorized Pulse Circuits For Computer Application

W. N. CARROLL* and R. A. COOPPER*

This article describes a group of transistorized computer circuits which combine the simplicity of Direct Coupled Transistor Logic and the speed of more complex circuitry. These 10 megapulse transformer coupled circuits were designed for an experimental computer which combined pure pulse techniques and parallel computer organization. The pulse system discussed herein makes use of novel circuit techniques which minimize the component count and allows the logic to be performed without the extensive use of delay lines. The non-saturating circuits which produce 1 volt, 40 millimicrosecond pulses, use p-n-p drift transistors, a single power supply, and drive into matched lines. Four basic circuits, the AND, OR, Storage, and Amplifier are used to perform all the necessary logical functions.

IN ORDER TO develop a reliable high speed digital computer for military applications, the Military Products Division of IBM initiated early in 1957, a program designed to evaluate the various different transistorized computing circuits. The investigations consisted of compiling a list of all the circuit characteristics considered important to reliable high speed computers such as the component count, the driving capability, ease of maintenance, speed, etc. The circuits were then rated against these characteristics in order to determine the most desirable computing circuit. One of the circuit types investigated was the Pure Pulse Circuitry, that is, all data are in the form of pulses which are short compared to the repetition period: two distinct stable *d-c* states do not exist.

Logically these circuits can represent a 1 by a pulse and a 0 by the absence of a pulse. While it is true that previous machines have been built using pulse techniques the data handling has been, in general, a serial process. In order to process data serially and to compete favorably in speed with present day parallel techniques, a pulse repetition rate in excess of the operational parameters of present day transistors would have been required. However, since pulse circuits did offer many advantages, a program was embarked on to investigate the potential of pulse circuitry in a parallel organized computer. The initial investigation proved very encouraging and it was decided to demonstrate the feasibility of the parallel pulse mode with a small model. To simulate accurately the problems of a large scale computer, the model was to consist of all the basic computer parts: Arithmetic Unit, Control Section, Memory, Input-Output. It was also decided that the size of the model be limited to that which could provide a maximum amount of data with a minimum outlay of money and manpower. Because large machine word lengths are usually broken into octal bits, we used a 2 octal bit word length, that is, 6 bits plus a sign bit. The logical layout for this model is shown in *Fig. 1*.

The upper left hand corner of *Fig. 1* is the Program Memory of the model. Pulse information is fed into the system at this point and is controlled by a Pulse Type Program Counter, a Decoder, and an IBM punched card. The upper right hand corner of the illustration shows a Data Memory consisting of 16 DC Flip Flop Storage registers and a Pulse Type Memory Address registers and Decoders. In the lower left hand corner is the Control Section. Three bits of the word length are used to provide the 8 instructions used. This information is transferred in parallel to the operation register and is decoded. A synchronized time pulse distributor is then used in conjunction with the decoded information to activate the command lines. The Arithmetic Section is located in the lower right hand corner of the figure. Data is fed in parallel from the Data Memory or the Load Gates into the A Register. The A Register can, in turn, transfer information into the accumulator. The adder is operated in parallel allowing a carry 1 or a carry 0 to ripple through the adder in order to attain the correct sums, which are then placed in the accumulator. Multiplications are performed by a series of adds occurring at a repetition rate of 10 megacycles. The B Register allows for the storage of the double word length arising from multiplication. Shifts right

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d left, complements and transfers can be performed the Arithmetic Section.

Having specified the logical functions of the model, listing of specifications and ground rules was set up order to guide the circuit design. The specified ound rules are (1) one power supply (—10 volts),) diffused base transistors (PNP), (3) 10 mega-ulse, (4) branching (six), (5) minimum number of mponents, (6) direct coupled, (7) coaxial lines 70 ohms), (8) maximum junction temperature 30°C) and (9) minimum use of delay lines. A dis-ussion of these ground rules follows.

To eliminate the need for On, Off voltage sequenc-ng, to improve reliability, and to reduce the power quipment, only one power supply was allowed. The alue of this supply was determined by the require-ents of the circuits and the transistor specifications. repetition rate of 10 megacycles was required, ence a high frequency *p-n-p* diffused base transistor as used. A study of previous machine circuits and heir driving problems indicated that a circuit with a ranching or driving ability of 6, would meet better han 85% of all driving requirements. To minimize ircuit complexity and to improve reliability, a direct oupled circuit utilizing a minimum of components was desired. At 10 megacycles it was felt that signal ransmission would have to take place over coaxial ines. Accordingly, subminiature 70-ohm cable was used. The requirement to drive 6 terminated coaxial ines in parallel placed an equivalent 11-ohm load at the circuit output. If only 3 or 4 coaxial lines were driven in parallel, appropriate terminating resistors would be placed across the circuit output to keep the load constant.

To obtain 10 years of transistor life, it was decided that the transistor must be limited to a peak junction temperature of 60°C. Below 60°C chemical action within the germanium would be held at a minimum. This specification was arrived at through the combined efforts of IBM's component reliability group, and the transistor manufacturer. To meet this specification with an ambient temperature of 45°C, we limited the peak power dissipation to 80 *mw.* and the average power to 20 *mw.*, at 10 *mc.* Previous pulse machines used numerous delay lines to avoid timing problems. The pulse model logic however is arranged so as to minimize the use of delay lines in order to reduce cost and size. Using these ground rules the pulse model circuits were designed.

Figure 2 includes the schematic of the Basic Pulse Amplifier. To limit the power dissipation within the transistor and to keep the device out of saturation while providing suitable inputs to the next stage, an 8:1 inverting type transformer utilizing a small toroidal ferrite core material was designed.

The resistor in the emitter circuit provides negative degeneration in order to minimize the dependence of the circuit performance upon variations in gain. The input, a standard 1 volt negative pulse, produces a positive 8 volt pulse on the primary of the transformer which in turn generates a 1 volt negative pulse at the output of the secondary. By limiting the voltage on the collector to an 8 volt pulse (by the action of the degeneration resistor, and the transformer reactance), the saturation region is not entered. To operate successfully at 10 *mc.*, the pulse width had to be short with respect to the pulse period. A maximum pulse width of 40 millimicroseconds or 40% of the pulse period was used.

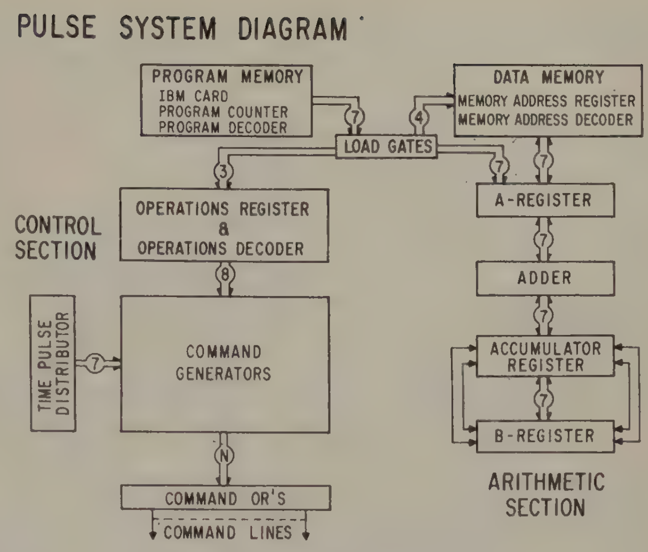

FIGURE 1.

Fig. 1—**Parallel System Diagram. Depicts the organization of a parallel (six bits plus sign-word length), 10 megapulse, transistorized, one complement system, single address machine. The machine also has eight instructions, 16 words of data memory and 32 words of program memory.**

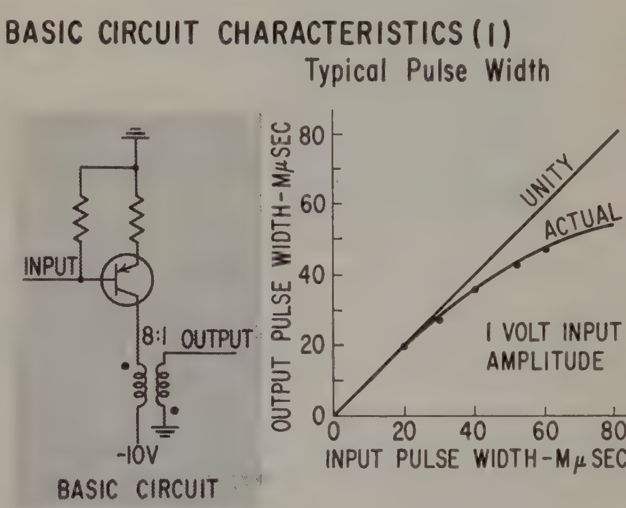

FIGURE 2

Fig. 2—**Basic Circuit Characteristic (1). Shown with the basic circuit is the pulse width transfer characteristic. Maximum allowable width within the model is 40 millimicrosecond.**

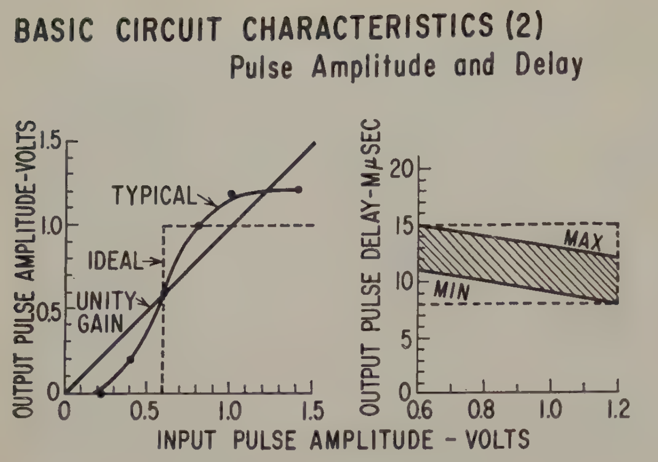

Fig. 3—**Basic Circuit Characteristic (2). Shown is the variation in pulse amplitude from the ideal and unity. Pulse delay is plotted for varying input amplitude. The delay is not a function of frequency.**

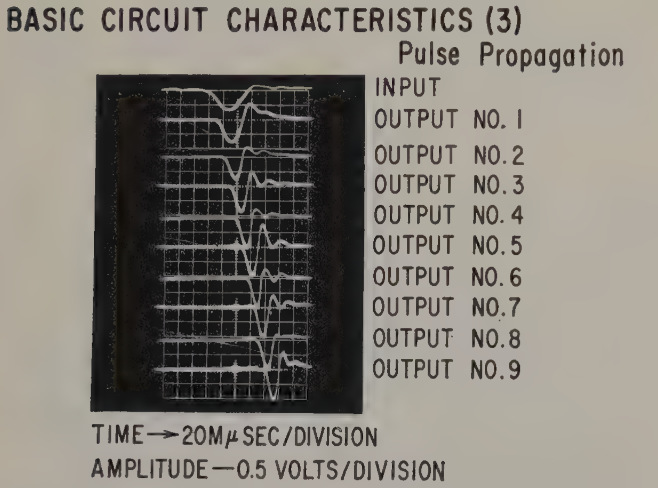

Fig. 4—**Basic Circuit Characteristic (3). Pulse propagation time for a pulse passing through nine series pulse amplifiers.**

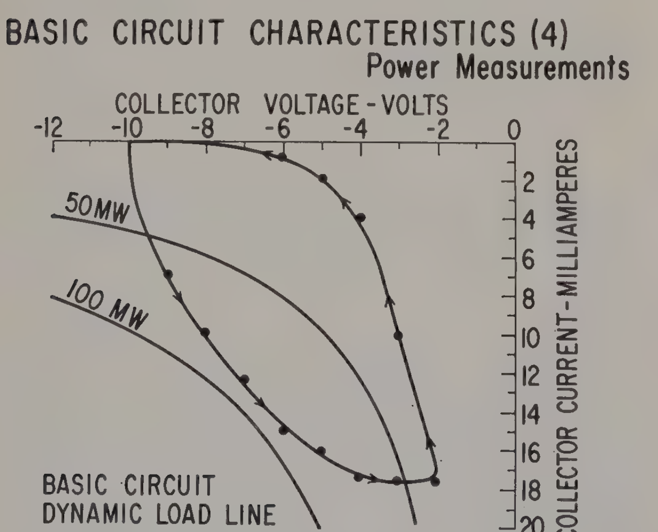

Fig. 5—**Basic Circuit Characteristic (4). Power measurements—shows the dynamic I_c, V_c transistor characteristics of the circuit during application of the 40 millimicrosecond, $-1V$ pulse. Maximum peak power of 80 milliwatts was experienced in the transistor.**

In order to maintain the pulse shape, the circuit was designed to narrow the applied pulse. On the right hand of *Fig. 2* is a typical transfer characteristic for pulse width. This characteristic is plotted for a constant one volt amplitude input. Pulse widths larger than 20 millimicroseconds tend to narrow.

Figure 3 shows the voltage transfer characteristic of the pulse amplifier. Ideally, one would desire a constant output amplitude for any input greater than the specified value, and a zero output for inputs below this value. This type of characteristic is shown in the dotted lines. An attempt was made to design the circuit characteristics as close as possible to the ideal. The solid line shows the actual curve obtained. It can be seen from this characteristic that input pulses greater than 0.6 volts will produce output pulses which tend toward 1.2 volts. The lower portion of the curve is a result of the input characteristics of the transistor. The upper portion is a result of the transformer reactance.

On the right hand side of *Fig. 3* are the circuit delay characteristics. To provide logical functions without the use of delay lines, it is necessary that all the circuits have relatively constant delays. The constant delays determine the time of arrival of pulses at subsequent circuits. The variation of all the circuits from maximum to minimum, while operating under worst conditions, is only 7 millimicroseconds. This delay is a result of input amplitude, and is independent of pulse width and frequency. The delay is a result of three specific delays, (1) the transformer which is approximately 1.5 millimicroseconds and a function of the placement of the windings, (2) the transistor which is approximately 5 millimicroseconds, and (3) the delay in overcoming the base input threshold voltage. It

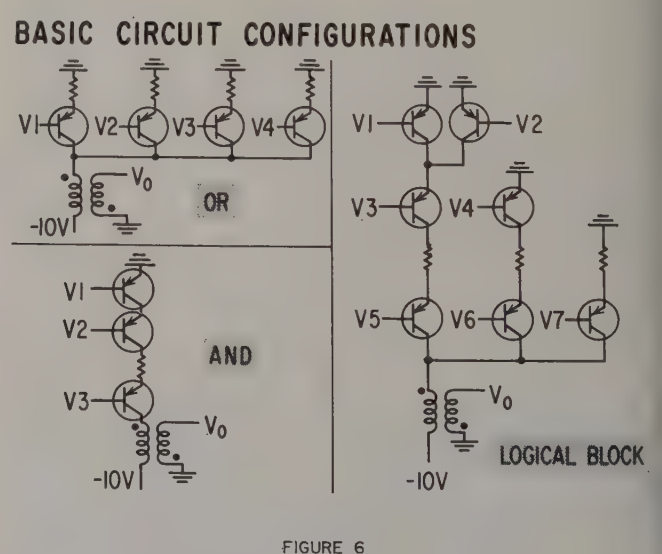

Fig. 6—**Basic Circuit Configurations. Basic circuits of AND, OR, and logical blocks are shown. These three circuits are capable of performing most of the pulse logic for the machine.**

this latter delay which is a function of the pulse amplitude.

Figure 4 shows the action of all the previously mentioned characteristics as a pulse propagates through the series circuits. These photographs were taken on an oscilloscope capable of resolving a 7 millimicrosecond wavefront. The vertical scale is ½ volt per division, and horizontally, 20 millimicroseconds per division. The input pulse is approximately 0.6 volts in amplitude and 50 millimicroseconds wide. The first four circuits tend to narrow the pulse and increase the amplitude.

The output of the fourth stage is a 1 volt 20 millimicroseconds pulse, which propagates through the remaining 5 circuits without further changes. The delay through the system is 85 millimicroseconds with the maximum circuit delay of 10 millimicroseconds and the minimum delay of 8 millimicroseconds.

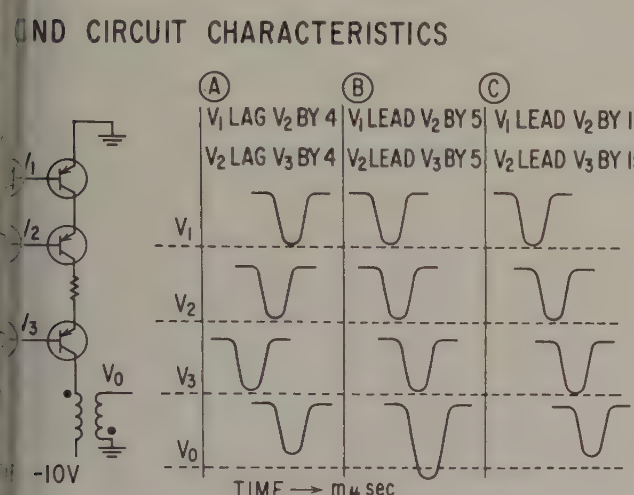

FIGURE 7

Fig. 7—AND Circuit Characteristics. This curve presents the asynchronous input variations which permit acceptable operation for the three-way AND circuit.

To keep the power dissipation within the limits specified in the ground rules, it was necessary to make dynamic measurements of collector power. The dynamic load lines of the various circuits were recorded. Shown in *Fig. 5* is the dynamic load line for the Basic Pulse Amplifier. The curve shows a peak power occurring at approximately 80 milliwatts on the leading edge. The average power for this pulse is below 20 *mw* at 10 *mc*. The direction of the curve shown here indicates a capacitive load. Capacitive loads in the system generally arise from collector capacitances of other (OR) circuit inputs, inputs to the storage circuit, and strays. If the load on the transistor were inductive, the direction in which the load is traversed would be in the opposite direction and the power would occur at the trailing edge of the pulse.

The Basic Pulse Amplifier as described in *Figs. 2* thru *5* is used to form all the logical circuitry of the

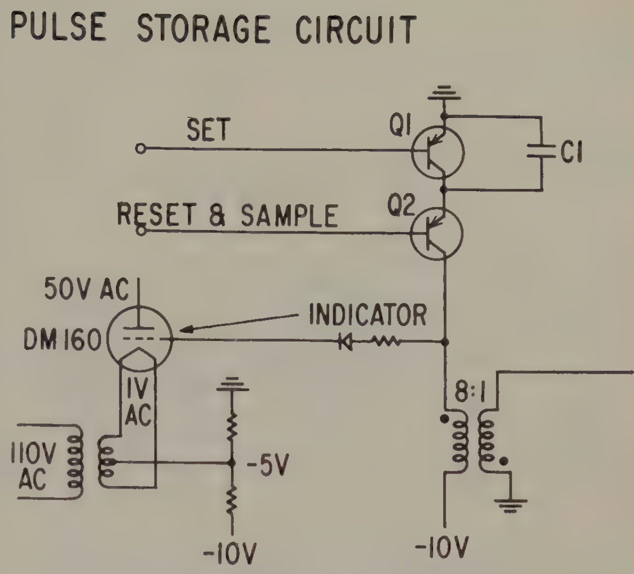

FIGURE 8

Fig. 8—Pulse Storage Circuit. Inputs to *Q2* charge *C1* and produce an output. *C1* will retain this charge and exhibit further action by *Q2* for 10 μsec. or until an input to *Q1* removes the charge.

computer. *Fig. 6* shows typical circuit configurations: OR circuits are formed by paralleling transistors, AND circuits by series connections. A maximum of 10 parallel or 3 series connections is allowed. Various direct coupled logical block circuits can also be formed.

One of the biggest problems in dealing with pulse type computing circuits is the synchronization of AND circuit inputs. It is at this circuit that pulses must arrive at closely controlled times. *Fig. 7* shows the degree of mismatch that can be allowed in the AND circuit. Here, an output pulse can be produced when simultaneous inputs are applied to *V1*, *V2*, and *V3*. However, the best condition occurs when each succeeding input is delayed just enough to allow the upper leg to turn on. That is *V1* followed by *V2* and then *V3* as shown in Column B. With reference to *V3*, the greatest mismatch in the lagging direction which still produces an acceptable output is shown in Column A. Here, each input lags the other by 4 millimicroseconds. The greatest degree of mismatch in the leading direction is shown in Column C. Here each input leads the other by 15 millimicroseconds. This means, with reference to *V3*, *V1* has a +8 to —30 millimicroseconds tolerance, and *V2* has a +4 to —15 millimicrosecond tolerance. Since all AND operations in the machine are taken only from simultaneous sources, the pulse arrives at the AND circuit well within these tolerances. The delay in the output of the circuit is determined from the last input, and was included in the delay characteristics previously shown.

Figure 8 shows the Pulse Storage Circuit. Since the pulses are not synchronized at intermediate logic

PULSE STORAGE CIRCUIT APPLICATION

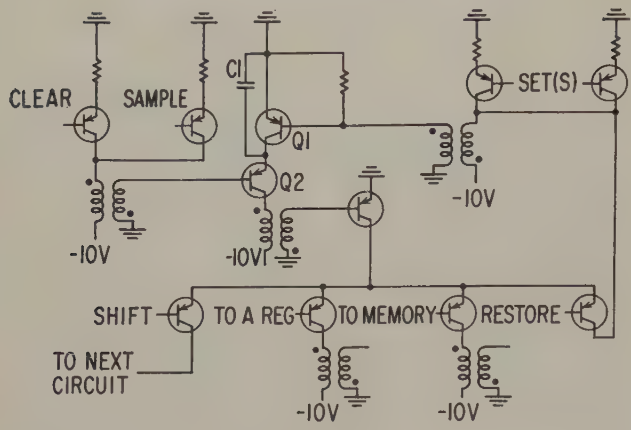

FIGURE 9

Fig. 9—Pulse Storage Circuit Application. Shown are "OR" inputs to storage circuit and output gates. Outputs are obtained by pulsing sample and logical function inputs. Restore replaces the information into the circuit after a read-out.

circuits, an asynchronous input was required. To retime the output information, synchronous outputs were specified. An intermediate storage medium was also required. By function this circuit is basically a capacitive storage circuit.

Assuming *C1* to be discharged, a standard negative pulse input applied to *Q2* will negatively charge *C1*, and the diode action of the emitter will prevent *C1* from discharging. The charging current will produce a standard output pulse. *C1* remaining charged will inhibit further inputs to *Q2* from producing an output. The value of *C1* was chosen such that its capacitive reactance to the pulse width was equal to the resistance of the degeneration resistor in the Basic Pulse Amplifier. It is also important that the available charge from *C1* will only produce a standard pulse output regardless of the input pulse width. The charge stored in *C1* will decay, slowly, due to the leakage currents of *Q1* and *Q2*. However, it is sufficient to prevent, under worst conditions, output pulses from being produced by pulses arriving at the base of *Q2* up to 5 μsec. Pulses arriving later at the base of *Q2* (prior to 5 μsec.) will reestablish the charge that had leaked off of *C1*, allowing an additional 5 μsec. of storage, but will not produce an output pulse. To set, a pulse is applied to the base of *Q1*. This pulse will remove the charge on *C1*, and will allow the next input to *Q2* to produce an output pulse. The timing of the set and reset, or sample pulses, need only be such that both are not pulsed simultaneously. To read out, a sample pulse is applied to *Q2*. If an output pulse is obtained a 1 is stored, if not, a 0 is stored.

The circuit, therefore, is much like a magnetic core: when a 1 is read out the information is destroyed, and if it is to be retained, the information must be replaced. To obtain long term storage, as when testing, the machine is pulsed at least once every 5 *u*sec.; provisions are also made for circuits which automatically regenerate the data.

Also shown on *Fig. 8* is the Indicator Circuit. This circuit utilizes a subminiature vacuum glow tube. Positive pulses at the collector will tend to charge, through the diode, the stray capacity of the line leading to the grid of the indicator. This action raises the bias on the grid to that of the cathode, the tube then conducts and produces a glow. With no pulses at the collector, minus 10 volts is applied to the grid resulting in cutoff.

Figure 9 shows a typical pulse storage circuit application such as the A register. The shaded area is the basic storage circuit. OR circuit inputs to *Q1* and *Q2* are shown, as well as the output gates. If an information transfer is made to memory, for example, the sample input, and the memory gate input would be pulsed. If a pulse output were obtained from the storage circuit, it would pulse the upper leg of the output gate. This pulse, in synchronism with the Memory Input Gate, would produce an output on the line leading to Memory. To restore, the sample input, and the restore gate could be pulsed. *Fig. 9* shows that the restore gate is essentially an OR input to the base of *Q1*, hence the capacitor *C1* (being charged by the sample pulse) would subsequently be discharged by the restore pulse, arriving at *Q1*. Three frames of equipment and 2200 *p-n-p* type transistors are used. The 10 megapulse circuitry utilizes 1848 Philco diffused base transistors, (these units, while originally manufactured solely for IBM, are very similar to the commercially available 2N501), 128 2N393 units and 224 2N240 units are also used (mainly in the memory). The performance data of this machine is listed as follows.

1. All logical circuits are capable of operating with reliable margins at 10 *mc*.
2. Set and clear operation of the storage circuit can be accomplished at 25 *mc*.
3. All data handling is accomplished in a parallel mode.
4. All circuits can propagate data with a maximum delay of 15 millimicroseconds and a minimum delay of 8 millimicroseconds.
5. Add operations can be performed at an average rate of 12 millimicroseconds per bit.
6. Multiply can be performed at a 10 *mc*. rate.
7. A single power supply supplies all the power.
8. The pulse circuits consume 3 watts of power.
9. A reduction in components has been achieved. The model uses 1800 resistors, 828 transformers and 236 capacitors.
10. A 32 step program enables the machine to accurately simulate full scale machine operation.

Of particular importance is the fact that extrapolating the performance data to a 20 bit word length, parallel pulse techniques will allow, with 1 μsec. overlap memories, an instruction rate of greater than 1 million instructions per second.

Transistor Bilateral Switches

PART 1

WM. M. COOK* and PIER L. BARGELLINI‡

In many electronic equipments large numbers of electro-mechanical relays are used for low level *a-c* and *d-c* signal switching. At present, transistors are being widely used to replace relays in *d-c* switching and the techniques in this area are reasonably well-known. The application of transistors as *a-c* switching elements has received much less attention. The purpose of this article is to present techniques for replacing *a-c* signal relays with transistor bilateral switches. Part 1, in this issue, discusses theory; part 2 in the next issue of Semiconductor Products discusses application.

TRANSISTOR bilateral switching can provide effective means for switching *a-c* signal paths. The ON to OFF isolation ratio is in the order of 100 *db* at low frequencies and as high as 60 *db* at ten megacycles; and ON impedances in the range of 0.5 to 10 ohms are obtained for low power germanium transistors. However, a number of difficulties in applying transistors to this use become evident. These include such factors as determining proper biasing, obtaining adequate signal isolation, and reducing d-c components. Some of the techniques which may be used to obtain effective Transistor Bilateral Switches for *a-c* signal applications are presented in this paper.

Before introducing these techniques a brief discussion of the bilateral mode of operation of symmetrical transistors is presented. Equivalent circuits are then used to analyze the effects of transistor and circuit parameters on switch performance. Multiple transistor switch circuit techniques are then shown which will overcome some of the more pronounced deficiencies of single unit circuits.

Characteristics of a Switch

An ideal switch offers zero impedance when closed and infinite impedance when opened. A realizable switch can be described as an ideal switch with a low external series resistance, a high parallel resistance and shunt capacitance. The operating conditions of such a switch can be represented in the manner shown in *Fig. 1*. The line R_s represents the series resistance and indicates the voltage drop across the closed (ON) switch. The line R_p represents the open (OFF) impedance and indicates the leakage current of the switch. The ON and OFF states of the electro-mechanical switch shown in Fig. 1 are determined by a control signal at the control input terminals. The relay is normally at least a four terminal device in that it has independent control and signal circuits, and consequently, there is little interaction between the control and signal. Since the characteristics represented are linear for both positive and negative signals the switch is satisfactory for *a-c* operation. When V_{IN} is an *a-c* voltage, then R_S and R_p represent the loci of operating points in the ON and OFF condition respectively.

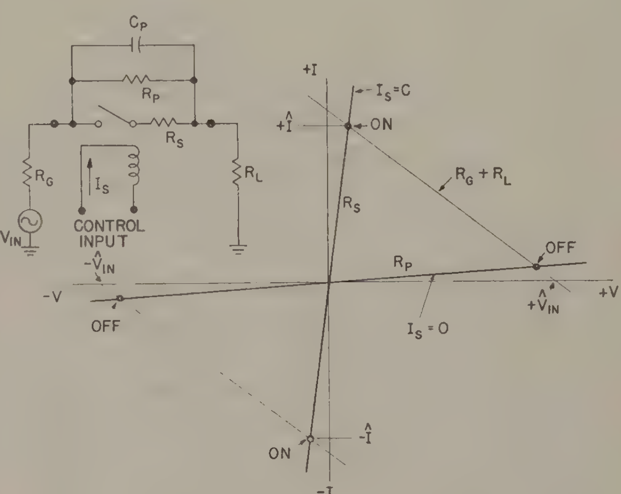

Fig. 1—Representation of the operating conditions of an electro-mechanical switch.

General Discussion of Bilateral Switching with Transistors

In *Fig. 2*, the bilateral characteristics of a nearly-symmetrical *n-p-n* transistor are given. The regions of similarity between the previous switch and the nearly symmetrical transistor characteristics are apparent. The current saturation region where the transistor offers a low impedance is similar to the ON condition of the previous switch. The current cutoff region where the transistor offers a high impedance is similar to the OFF condition of the switch. However, the ON and OFF regions are both restricted as indicated by the sharp changes in slopes in the ON and OFF characteristics at their extremes.

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Consider the operation of the transistor in the circuit of *Fig. 2*. The transistor symbol shown here is used to indicate a symmetrical transistor. In order to keep the transistor in the OFF state both junctions must be reverse biased. Since the input voltage varies between $\pm\hat{V}_{IN}$, the reverse base voltage V_{BR} must be maintained more negative than the negative peak input voltage. When the input reaches its most positive value, the voltage across the collector-base input junction is:

$$V_{CB} = -(V_{BR} + \hat{V}_{IN}) < B\,V_{CB} \qquad 1)$$

This maximum reverse bias must not exceed the voltage breakdown of the collector-base junction. Therefore, the limits of the OFF condition are voltage breakdown and forward bias of the collector-base junction. The input voltage and the reverse bias must be chosen so that neither condition is exceeded.

If constant forward base current is supplied to the circuit the characteristic labeled I_B CONSTANT is obtained. When the input voltage is sufficiently positive, the transistor is in the normal common emitter mode of operation. The current through the transistor in this condition is determined by the normal current gain β_N and the base current. As the input becomes less positive the collector junction as well as the emitter junction becomes forward biased. The current through the device is now dependent upon the external circuit since the transistor now offers a low impedance. As the input swings through zero to negative values the base voltage will follow the collector voltage. At the current level determined by the inverted current gain, β_I, and the base current, the emitter will become reverse biased and operate as the collector. The transistor is then in the common collector mode of operation.

It is seen that the negative peak voltage drop is larger than the positive peak voltage drop for the load chosen and constant base current (this is due to the imperfect symmetry of the transistor, $\beta_N > \beta_I$). Consider the operation of the circuit when finite R_B and forward base voltage V_{BF} are employed. The R_B and V_{BF} are chosen so that the same positive peak drop is obtained. Since the transistor offers low impedance in saturation, its collector, emitter and base are at nearly the same potential. Consequently, the forward base voltage V_{BF} must be larger than the positive peak input signal in order to supply the base current required for saturation. As the input signal decreases from its maximum positive level the base current will increase. The characteristic obtained under these conditions is labeled I_B MODULATED in *Fig. 2*. The peak drops under this condition are nearly identical for the example chosen. It is possible to obtain symmetrically bilateral action with non-symmetrical units provided the proper base circuit parameters are chosen. However, the base circuit must be considered in relation to the signal circuit. It is often impossible to properly choose the base parameters because of undue loading of the signal circuit. In general, therefore, a symmetrical transistor is to be preferred.

The limits of the ON region are defined by the normal and inverted current gains β_N and β_I, and the magnitude of base current supplied. That is, the peak positive collector current must be less than $I_B\ \beta_N$ while $-I_C$ must be less than $I_B\ (B_I + 1)$. The reason for the difference in the two expressions is that the collector becomes the emitter when V_{IN} is negative and I_B flows in the collector circuit. For low, reasonably linear ON resistance the maximum I_C should be no more than 2/3 the capability indicated by the I_B and the current gains. Over this range the saturation (ON) resistance is given by

$$R_S \approx \frac{\Delta V_{CE}}{\Delta I_C} \qquad 2)$$

In *Fig. 3*, the waveforms obtained in a series switch, similar to that in *Fig. 2*, and in a shunt switch are shown. Both sets of waveforms are presented with respect to the state of the *p-n-p* switch transistor. The series switch waveforms agree wtih the preceding discussion. The voltage across the OFF transistor, V_{CE}, is

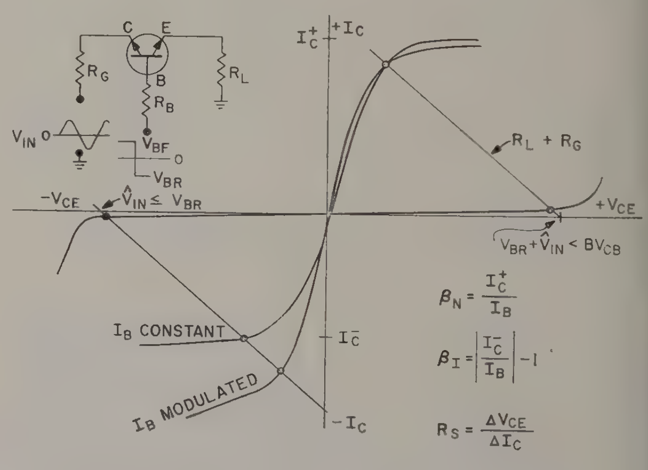


Fig. 2—Characteristics of a transistor used as a bilateral switch.

essentially equal to the input voltage and the output is negligibly small. The voltage across the input (collector-base) junction (V_{BC}) varies from a small minimum value to greater than twice the input voltage. The voltage across the output (emitter-base) junction (V_{BE}) is constant and essentially equal to V_{BR}. The voltage drop across R_B due to reverse base current I_{BR} is usually negligible at room temperature. However, this drop should be considered in choosing V_{BR} for high temperature operation.

When the base voltage is changed from V_{BR} to a forward voltage, V_{BF}, the transistor will saturate pro-

[1] J. J. Ebers, J. L. Moll, Large Signal Behavior of Junction Transistors, Proc. IRE, Vol. 42, No. 12, Dec. 1954.

ed the proper conditions are satisfied. The forward base current I_B is composed of the *d-c* component I_B and a component due to the effects of V_{IN}. Since the minimum base current occurs when the input signal is maximum, sufficient base current must be supplied under these conditions to obtain something less than the maximum allowable voltage drop across the transistor.

The output voltage V_O is attenuated with respect to the input and also contains a *d-c* component. The attenuation is in part the normal voltage division between a source and load resistance. However, R_B has a shunting effect upon R_L so that the attenuation will be somewhat greater. The *d-c* component in the out-

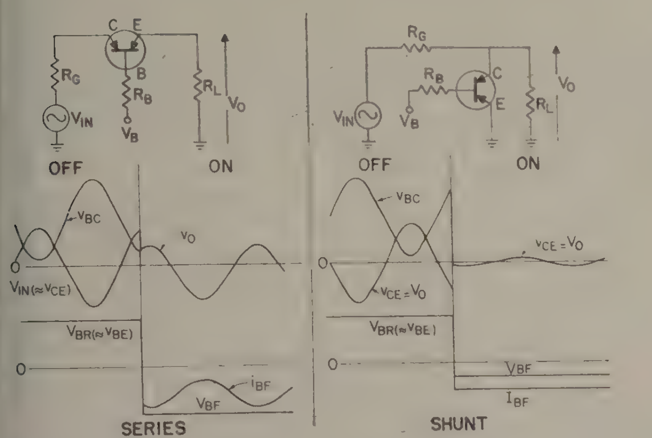


Fig. 3—Transistor bilateral switch waveforms.

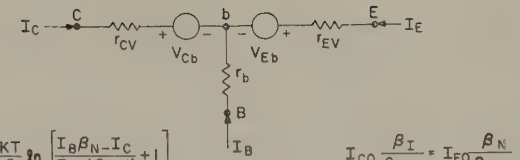
put is due to the base current, which flows in the source and load. The current gains of the transistor determine the amount of base current required for particular signal circuit requirements; and consequently, the magnitude of offset and the values of R_B and V_{BF}.

The requirements for the OFF condition of the transistor in the shunt configuration are essentially the same as for the OFF transistor in the series configuration. The shunt circuit is in the transmission state when the switch element is OFF. However, the operation of the ON transistor in the shunt configuration is different. The forward base voltage need not be greater than the input voltage. The base current is not modulated and the *d-c* voltage component is low in the range of 5 to 15 *mv*. However, the degree of OFF isolation obtainable will in general be lower for the shunt configuration.

Equivalent Circuits of Transistors

Several of the difficulties which arise when using transistors as relay elements have been briefly discussed in the preceding section. In order to fully evaluate the performance of transistors in series and shunt switching circuits it is desirable to represent the transistor in equivalent circuit form. This is shown in *Fig. 4*.

In the saturation region both junctions are forward biased and their impedances are low. Consequently,



$$V_{Cb} = \pm \frac{KT}{q} \ln \left[\frac{I_B \beta_N - I_C}{I_{CO}(\beta_N + 1)} + 1 \right] \qquad I_{CO} \frac{\beta_I}{\beta_{I+1}} = I_{EO} \frac{\beta_N}{\beta_{N+1}}$$

$$V_{Eb} = \pm \frac{KT}{q} \ln \left[\frac{I_B \beta_I - I_E}{I_{EO}(\beta_I + 1)} + 1 \right] \qquad R_S = \frac{KT}{q} \left[\frac{1}{\beta_N I_B - I_C} + \frac{1}{(\beta_I + 1) I_B + I_C} \right]$$

$$V_{CE} = \pm \frac{KT}{q} \ln \left[\frac{I_B - \frac{I_C}{\beta_N} + I_{CO}\left(\frac{\beta_N + 1}{\beta_N}\right)}{I_B + \frac{I_C + I_B}{\beta_I} + I_{EO}\left(\frac{\beta_I + 1}{\beta_I}\right)} \right]$$

Fig. 4.—Equivalent circuit representation of transistor as a switching element in the "ON" condition.

the currents are determined primarily by the external circuit. In saturation, it is then convenient to write the junction voltage drops V_{Cb} and V_{Eb} in terms of the external currents. Ebers and Moll have shown that the junction voltages can be expressed as[1]

$$V_{Cb} = \pm \frac{kT}{q} \ln \left[1 - \frac{I_C + \alpha_N I_E}{I_{CO}} \right] \qquad 3)$$

$$V_{Eb} = \pm \frac{kT}{q} \ln \left[1 - \frac{I_E + \alpha_I I_C}{I_{EO}} \right] \qquad 4)$$

where k = Boltzman's constant,

T = Absolute temperature in degrees Kelvin,

q = Charge of an electron,

α_N = The normal large signal grounded base current transfer ratio,

α_I = The large signal grounded base current transfer ratio when the functions of emitter and collector are reversed.

I_{CO} = The reverse thermal current of the collector junction with the emitter open, and

I_{EO} = The reverse thermal current of the emitter junction with the collector open.

V_{Cb} and V_{Eb} represent the junction voltages from the *p* to the *n* region, and the equations apply to either *p-n-p or n-p-n* transistors. The polarities indicated in *Fig. 4* are those for a *p-n-p* transistor.

Equations (3 and 4) were derived for the grounded base connection. Since the base is the control input terminal in bilateral switching it is more convenient to have the junction voltages expressed in terms of I_B, β_N and β_I. This is easily accomplished using the relationships:

$$\beta_N = \frac{\alpha_N}{\alpha_N + 1} \qquad 5)$$

$$\beta_I = \frac{\alpha_I}{\alpha_I + 1} \qquad 6)$$

$$I_C + I_B + I_E = 0 \qquad 7)$$

Making the appropriate substitutions in Eq. (3 and 4) yields:

$$V_{Cb} = \pm \frac{kT}{q} \ln \left[\frac{\beta_N I_B - I_C}{(\beta_N+1) I_{CO}} + 1 \right] \quad 8)$$

$$V_{Eb} = \pm \frac{kT}{q} \ln \left[\frac{\beta_I I_B - I_E}{(\beta_I+1) I_{EO}} + 1 \right] \quad 9)$$

The base resistance r_b in the equivalent circuit is the base spreading resistance measured in the saturation region. The resistance r_{CV} and V_{EV} represent the extrinsic resistances of the junction materials. These extrinsic elements have not been taken into account in the above equations, since they can be ignored in the majority of applications.

In the ON transistor switch the voltage drop and the saturation resistance are important factors. The voltage drop across the switch is the difference between V_{Cb} and V_{Eb} using the relationship between the cutoff currents:

$$\frac{\beta_I}{\beta_I + 1} I_{CO} = \frac{\beta_N}{\beta_N + 1} I_{EO} \quad 10)$$

The voltage drop V, can be expressed as:

$$V_{CE} = \pm \frac{kT}{q} \ln \left[\frac{I_B \beta_N - I_C + I_{CO} (\beta_N+1)}{I_B (\beta_I+1) + I_C + I_{EO} (\beta_I+1)} \cdot \frac{\beta_I}{\beta_N} \right] \quad 11)$$

As the limits of the saturation region are approached V_{CE} as expressed above approaches $\pm\infty$. This, of course, is not the actual case, since the voltage cannot go beyond the supply voltage. What is indicated is that the voltage drop is now independent of the external circuit. The transistor is then in the active region and the above expressions are no longer useful. The limits of the saturation region are the points where either junction becomes reverse biased.

The saturation resistance, R_S, of the transistor is obtained by differentiating V_{CE} with respect to I_C and is given by:

$$R_S = \frac{d V_{CE}}{d I_C} = \frac{kT}{q} \left[\frac{1}{I_B \beta_N - I_C + I_{CO} (\beta_N+1)} + \frac{1}{I_B (\beta_I+1) + I_C + I_{EO} (\beta_I+1)} \right] \quad 12)$$

The terms involving I_{CO} and I_{EO} in the above equations can normally be neglected.

Examination of Eq. (11 and 12) when $I_C = 0$ reveals several significant points. The voltage drop, V_{CE}, under these conditions is the *d-c* voltage component inherent in the transistor and is given by

$$V_{CE} \Big|_{I_C=0} = \pm \frac{kT}{q} \ln \left[\frac{\beta_I}{\beta_I + 1} \right] \quad 13)$$

This expression indicates that the residual *d-c* voltage across the transistor is determined primarily by the inverted current gain. This is the residual *d-c* voltage in the shunt configuration. However, it is only a minor part of the *d-c* voltage component in the series configuration. The saturation resistance under this condition is given by:

$$R_S \Big|_{I_C=0} = \frac{kT}{q} \frac{1}{I_B} \left[\frac{1}{\beta_N} + \frac{1}{\beta_I + 1} \right] \quad 14)$$

This expression shows that the saturation resistance is inversely proportional to the base current and the current gains. The minimum value of R_S will be limited by the current gain fall-off at high base currents and the bulk resistances r_{CV} and r_{EV} which have previously been neglected.

The ON equivalent circuit of *Fig. 4* is unwieldy for use in the analysis of switching circuits. The approximate ON equivalent circuit of *Fig. 5* is much more convenient. The elements R_{CS} and R_{ES} can be obtained from the characteristics of *Fig. 2* or Equation (13) and the expressions:

$$R_{CS} = \frac{\beta_I}{\beta_N + \beta_I} R_S \quad 15)$$

$$R_{ES} = \frac{\beta_N}{\beta_N + \beta_I} R_S \quad 16)$$

The base resistance, r_b, is the same in both equivalent circuits. The battery V_b represents the voltage $V_{bC} = V_{bE}$ when $V_{CE} = 0$. The base elements can be obtained from the base input characteristics for the condition $V_{CE} = 0$. This equivalent circuit is valid for constant I_B and moderate variations in I_C. It is reasonably accurate for varying base current if the saturation resistance is determined from the I_C, V_{CE} characteristic under the same conditions of the base current.

The OFF equivalent circuit of the transistor is also given in *Fig. 5*. The capacitances C_{Cb} and C_{Eb} are the junction transition capacitances and for alloy junction transistors are given by:

$$C_j = \frac{a}{\sqrt{\phi_j + V_j}} \quad 17)$$

where: a = a proportionality constant
ϕj = the junction barrier voltage, and
The positive sign of V_j is taken when the junction is reverse biased.

It should be noted that these capacitances are present in the ON transistor in parallel with the junction saturation resistances. However, their impedances are normally large compared to R_{CS} and R_{ES} and can therefore be neglected.

The resistance elements in the OFF equivalent circuit are the leakage resistances of the junctions. Since they are strongly dependent upon surface conditions, it is difficult to accurately express their values. In

sent day transistors, the leakage resistances are in range of one to ten megohms. Consequently, they usually be neglected when compared to the value the capacitive reactance even at moderately low quencies (100 *kc* and above).

The currents I_{CR} and I_{ER} are the reverse thermal rents of the junctions when both are reverse biased. ey are lower than the single junction reverse curits I_{CO} and I_{EO} and are given by:

$$I_{CR} = \frac{I_{CO}\,(\beta_N + 1)}{\beta_N + \beta_I + 1} \qquad 18)$$

$$I_{ER} = \frac{I_{EO}\,(\beta_I + 1)}{\beta_N + \beta_I + 1} \qquad 19)$$

a symmetrical transistor I_{CR} and I_{ER} are approxiately half the I_{CO} and I_{EO}. In many applications, here *a-c* signals are involved and the impedance vels are low, the cutoff currents can also be negcted.

The base resistance in the OFF transistor is somehat higher than in the ON transistor. This is due the increase in the resistivity of the base material ith decreasing current concentration. In determing the effect of the OFF transistor in shunt and eries switches, the capacitances and base resistance re the dominating factors.

he Effect of Transistor Parameters in Shunt nd Series Switches

In the shunt switch of *Fig. 6*, the transistor is relaced by its OFF and ON equivalent circuits. When he transistor is in the OFF state, it is seen that the ignal transmission will be limited at high frequenies by the capacity loading of the transistor. The ignal attenuation is given by:

$$\text{Atten.} = +\,20 \text{ Log} \frac{V_{IN}}{V_O}$$

$$= +\,20 \text{ Log} \left| \frac{R_L + R_G}{R_L} + j\,\omega\, C_{Cb}\, R_B \cdot \left[\frac{1 + j\,\omega\, C_{Eb}\, R'_B}{1 + j\,\omega\,(C_{Eb} + C_{Cb})\, R'_B} \right] \right| \qquad 20)$$

where $R'_B = R_b + r_b$

To optimize the high frequency performance of the shunt switch R_B should be large. Since shunt switches are generally used in high impedance circuits, the effects of I_{CR} on the *d-c* voltage component should be considered, particularly for high temperature operation. The *d-c* voltage component due to I_{CR} is given by:

$$V_O \Big|_{V_{IN}=0} = I_{CR} \frac{R_L\, R_G}{R_L + R_G} \qquad 21)$$

When the transistor is ON, the signal current is shunted to ground. The output voltage remaining is

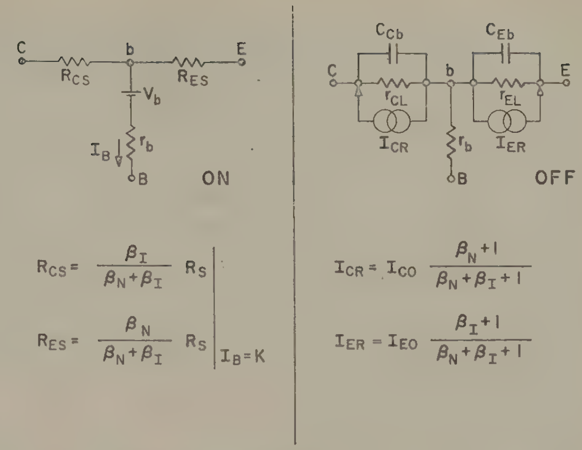


Fig. 5—"ON" and "OFF" equivalent circuits.

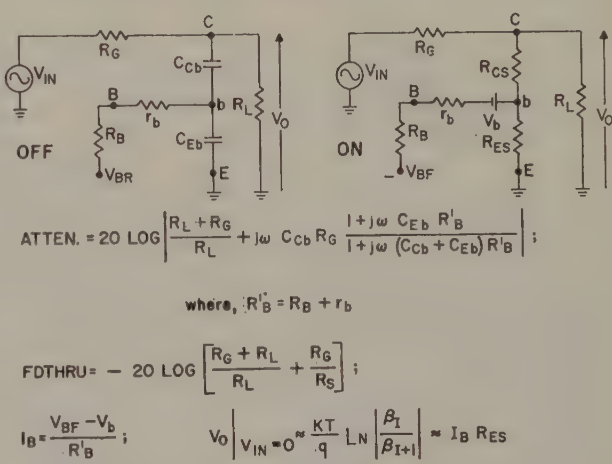


Fig. 6—Shunt switch transistor equivalent circuits.

due to the saturation resistance of the transistor plus the *d-c* voltage component. The signal feedthrough of the OFF circuit is given by:

$$\text{Feed thru} = -20 \text{ Log} \frac{V_{IN}}{V_O}$$

$$= -20 \text{ Log} \left[\frac{R_L + R_G}{R_L} + \frac{R_G}{R_S} \right] \qquad 22)$$

The degree of isolation obtainable is dependent upon the relative values of R_G, R_L, and R_S. The ON current of the transistor is given by

$$I_B = \frac{V_{BF} - V_b}{R'_B} \qquad 23)$$

the effect of the input signal on the base current is negligible. The *d-c* voltage component is given by Eq. (14) or

$$V_O \Big|_{V_{IN}=0} = I_B\, R_{ES} \qquad 24)$$

In the series switch of *Fig. 7* the transistor is replaced by its OFF and ON equivalent circuits. Since series switches are normally used in low impedance circuits, the effects of the OFF currents can normally

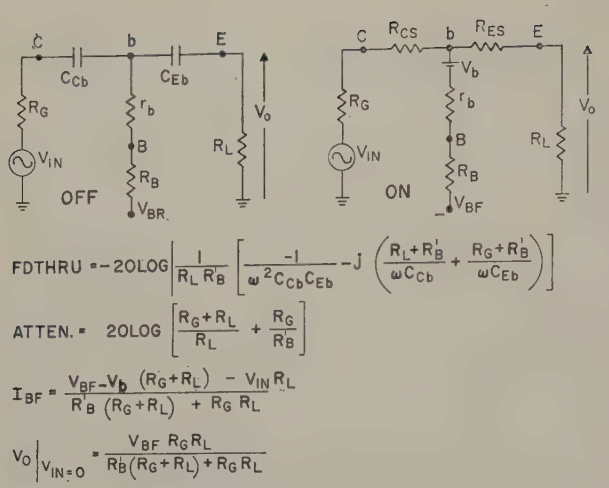


Fig. 7—Series switch transistor equivalent circuits.

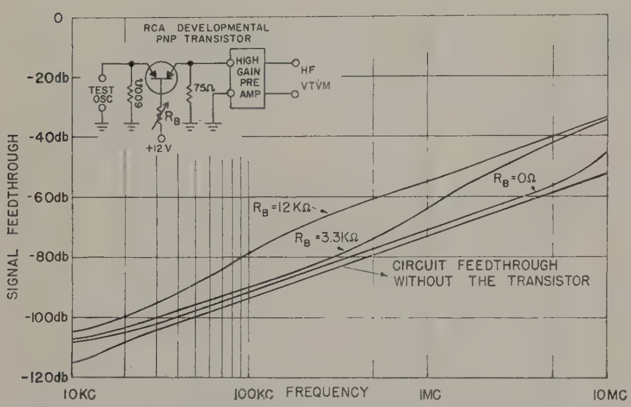


Fig. 8—Effect of R_B on feedthru in a series switch.

be neglected. In the OFF transistor at frequencies below

$$f_C = \frac{1}{2\,\pi\, C_{Cb}\, r_{CL}} \qquad f_E = \frac{1}{2\,\pi\, C_{Eb}\, r_{EL}} \qquad 25)$$

the effects of the junction capacitances can be neglected.

Under these conditions the signal feedthrough is

$$\text{Feed thru} = -20 \text{ Log} \left[\frac{r_{CL}\,(R_L + R'_B) + r_{EL}\,(R_G + R'_B) + r_{CL}\, r_{EL}}{R_L\, R'_B} \right] \qquad 26)$$

Above f_C and f_E the signal feedthrough is given by

$$\text{Feed thru} = -20 \text{ Log} \left| \frac{1}{R_L\, R'_B} \cdot \left[\frac{-1}{\omega^2\, C_{Cb}\, C_{Eb}} - j \left(\frac{R_L + R'_B}{\omega\, C_{Cb}} + \frac{R_G + R'_B}{\omega\, C_{Eb}} \right) \right] \right| \qquad 27)$$

In series switches R'_B is a very important factor in determining the feedthrough. To minimize feedthrough R'_B should be made as small as possible. In the limit, $R'_B > 0$, there would be no feedthrough regardless of the magnitude of the other parameters. The realizable limit of R'_B is approximately r_b. The effect of the external resistance R_B on feedthrough in series switches is shown in *Fig. 8*.

Junction capacitances are also important in determining the feedthrough. Consequently, transistors with low junction capacitances and low base resistance are required. Since the junction capacitances are functions of the junction voltages (Eq. 18) V_{BR} should be as high as possible.

The signal attenuation in the ON series switch is given by

$$\text{Atten.} \approx 20 \text{ Log} \left[\frac{R_G + R_L}{R_L} + \frac{R_G}{R'_B} \right] \qquad 28)$$

The saturation resistance of the transistor has been neglected since it is normally small compared to R_G and R_L. R_G is still a dominating factor and is required to be large to minimize ON attenuation. Since the OFF feedthrough at low frequencies is low even for moderate values of R_G the requirements of the ON and OFF condition can be satisfactorily compromised. When a high frequency switch is required, means must be used which will satisfy the requirements of both the OFF and ON conditions.

The base current in the ON series switch is given by

$$I_B \approx \frac{V_{BF} - V_b}{R'_B} - \frac{V_{IN}\, R_L}{R'_B\,(R_G + R_L)} \qquad 29)$$

This expression is valid when $R'_B >> R_G$ or R_L. This is the case for values of R_B consistent with low attenuation. The first term is the *d-c* component of base current while the second term is the modulation component. The minimum base current which must be supplied, when the input voltage is opposing, the base current is given by:

$$I_B\,(\text{min.}) = \frac{\pm V_{IN}}{\beta_N\,(R_G + R_L)} \qquad 30)$$

+ for *n-p-n*
− for *p-n-p*

I_B minimum should normally be at least 1.3 times this minimum value to ensure operation below the knee of the symmetrical characteristic.

The *d-c* voltage component at the load in the series switch is given by:

$$V_O \Big|_{V_{IN}=0} = \frac{(V_{BF} - V_b)\, R_G\, R_L}{R'_B\,(R_G + R_L) + R_G\, R_L} \qquad 31)$$

The *d-c* voltage component results from division of the forward base voltage between R_B in series with R_G and R_L in parallel.

The frequency response of a transistor in the active region has no direct effect upon the ON and OFF conditions in shunt or series switches. However, it is important in determining the transient response of the switch. The problem of transient response is beyond the scope of this article.

[TO BE CONTINUED]

A Germanium Alloy Transistor for High Temperature Operation

BERNARD REICH*

This article describes a transistor with temperature stable characteristics over a minimum operating range of 25°C to 100°C. Over the range of temperatures the current gain variation does not exceed 12%.

IN THE PAST few months, developmental samples of germanium transistors, capable of being stored at 100°C, have become available at these Laboratories; however, the characteristics of germanium devices operating in the neighborhood of 100°C have not been too well defined. Earlier work done at these Laboratories indicated degeneration of current gain and output impedance above 55-70°C.[1] Recently the author has made an analysis of the variation of current gain in transistors, and the results of this investigation indicated the significant factor causing this change.[2] On the basis of these results, a transistor has been designed with fairly stable temperature characteristics to 100°C. The purpose of this report is to indicate the design and the resultant operating characteristics of this device.

D-C Current Gain

It was decided for design purposes to choose a power transistor for discussion. Power transistors, because of function, usually operate at high junction temperatures; however, this operating temperature may vary with ambient conditions. It is important that variations in operating temperature do not appreciably alter the device characteristics. At junction temperatures above 70°C, degradation in current gain will alter the power gain of the device. In addition, the input and output impedances are also affected. The results obtained by the author indicate[2] that the base resistivity is a critical factor in "designing" temperature characteristics into devices provided that the conductivity of the emitter region can be controlled. Again for the purposes of design, a *p-n-p* device is chosen. Examination of the resistivity of *n*-type germanium as a function of temperature[3] indicates that 1.6 Ω-*cm* base material seemed reasonable for fairly stable gain characteristics between 50°C-100°C. For the purposes of "paper" design, the following parameters were chosen:

a. Emitter diameter, d_e—0.90 in.
b. Collector diameter, d_c—.120 in.
c. Base width, W—.002 in.
d. Emitter resistivity, ρ_e—.001 Ω-*cm*
e. Base resistivity, ρ_b—1.6 Ω-*cm* (25°C), critical
f. Base ring diameter, d_{br}—.170 in.

Based on this design information, the characteristics of the transistor were calculated. The calculations are based on equations derived by Messenger[4] and the current gain characteristic equation by Webster.[5]

With a choice of 1.6 Ω-*cm* as the base resistivity of the designed transistor, the diode breakdown voltages are then examined. The diode breakdown voltages are calculated from the following equation[4]:

$$V_D = C_7 \rho_b{}^K \qquad (1)$$

where V_D is the diode breakdown voltage,
C_7 is a design constant being 32 for *n*-type germanium,
K is a design constant of ½,
ρ_b is the base resistivity.

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[1]Maximum Operating Junction Temperature and Reliability, J. Mandelkorn, presented at the *Transistor Reliability Symposium*, September 1956.
[2]Temperature Sensitivity of Current Gain in Transistors, B. Reich *Trans. of IRE, PGED*, July 1958.
[3]Lecture 18, *Power Transistors*, L. Giacoletto, Pennsylvania State College Transistor Short Course.
[4]Transistor Design Equations, George C. Messenger, Philco Corporation, Philadelphia, Pa., Personal Communication.
[5]*Transistors I*, RCA, Princeton, N. J.

The design breakdown voltages for the emitter-to-base and collector-to-base diodes calculate to be 40 volts.

Also of importance in the design of a power transistor is the saturation current. The saturation current may be expressed as follows if the emitter and base are shorted and the collector and emitter diodes are back-biased[4]:

$$I_{co} = \frac{\rho_b A_c}{C_1 W} \tag{2}$$

where A_c is the collector area,
C_1 is an empirical constant 3.8×10^5 Ω-cm^2/amp
W is the base width.

It is found that the saturation current under these conditions is 61 microamperes.

Using the expression for alpha cut-off frequency[4]:

$$f_{c\alpha} = \frac{1.22D}{\pi W^2} \tag{3}$$

The alpha cut-off frequency is found to be 690 *kc/sec*.

Since this transistor has been designed primarily for high temperature operation, two important characteristics are now examined. These are current gain-emitter current characteristic, and the gain temperature characteristic. Using the expression for current gain[5]

$$\frac{1}{\beta} = \left[\frac{\sigma_b W}{\sigma_e L_e} + \frac{1}{2}\left(\frac{W}{L_b}\right)^2\right](1 + kI_E) + \frac{sWA_s}{D_p A} g(kI_E) \tag{4}$$

where $\sigma_b \sigma_e$ are the base and emitter conductivities,
W is the base width,
$L_b L_e$ are the diffusion distances in base and emitter,
A_s is the effective area around the emitter with which recombination takes place,
A is the total emitter area,
$g(kI_E)$ is a function which varies from unity to one-half as kI_E is increased,
D_p is the diffusion constant for holes,

$$k = \frac{W \mu_e}{A D_p \sigma_b}$$

and, s is the surface recombination velocity

It should be pointed out that this expression holds for small signal beta. *Fig. 1* is a curve of the small signal gain-emitter current characteristic of the transistor calculated to one ampere.

Figure 2 is a plot of the small signal current gain as a function of operating temperature to 100°C. The stability of this characteristic over the temperature range should be noted.

Although not too important a parameter in power transistor design, the collector resistance should not

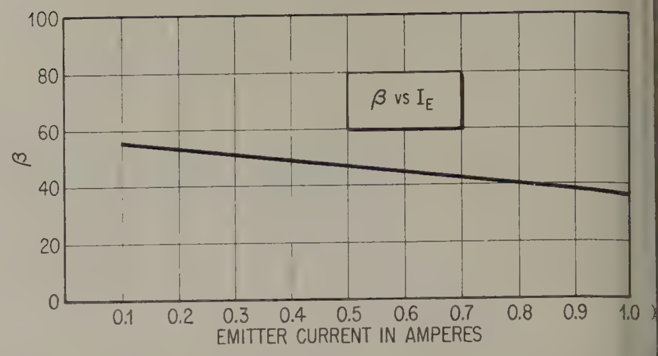

Fig. 1—Curve of small signal gain-emitter current characteristic calculated to one ampere.

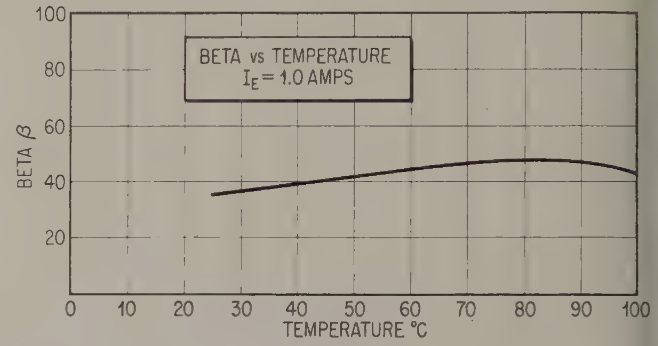

Fig. 2—Plot of the small signal current gain as a function of operating temperature to 100°C.

be completely overlooked, especially at high temperatures. Utilizing the expression for collector resistance[4]

$$r_c = \frac{2\beta W}{\left[a\, I_c\, C_5 \left(\frac{\rho_b}{V_{cb}}\right)^{\frac{1}{2}}\right]} \tag{5}$$

where β is the common emitter current gain
W is the base width
a is the common base current gain
I_c is the collector current
C_5 is a material constant 1.1×10^{-4} (farad-cm/volt sec)$^{1/2}$ for n-type germanium.

The collector resistance of the transistor at one ampere was calculated. Table I is a result of this calculation.

TABLE I
Variation of Collector Resistance with Temperature

r_c x 10^5 ohms	T °C
0.23	25
0.25	50
0.28	75
0.28	100

Paper designs serve as a useful basis for transistor characteristic approximations; however, the important conclusion must come from fabricated devices. After some investigation, the author was able to locate transistors fabricated near enough to the specifi-

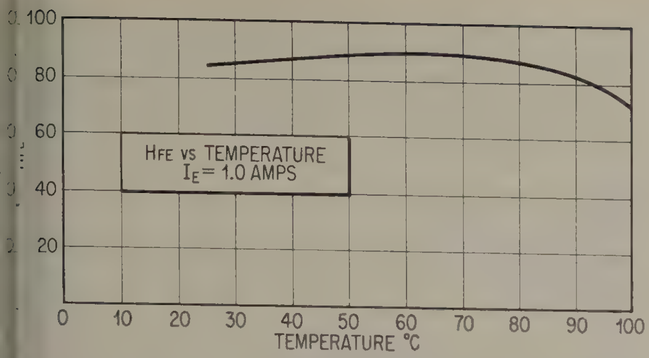

Fig. 3—Curve of the measured values of the large signal current gain as a function of operating temperature.

cations outlined previously to initiate experimental evaluation information. It was realized that these transistors in fabrication had some inherent differences due to process variations; however, the important design objective was investigated, the gain temperature characteristic.

The transistors obtained had base resistivities of 1.5 < ρ < 1.7 Ω-*cm*. The average of the units had the following characteristics:

I_{co} (Base-emitter shorted)	60 μa
V_D (Collector to base)	54 volts

The calculated value for I_{co} was 61 μa, and V_D 40 volts. The breakdown voltage calculated 14 volts lower than the average of the units measured. *Fig. 3* is a curve of the measured values of the large signal current gain as a function of operating temperature. Although the large signal current gain is plotted in *Fig. 3* no significant difference between this and beta is expected with respect to temperature sensitivity. The correlation of the curves shown in *Fig. 2* and *Fig. 3* seems very good. If the maximum deviations, defined as $\frac{\beta\ \text{max}-\beta\ \text{min}}{\beta\ \text{max}}$, are compared, the curve in *Fig. 2* has a maximum deviation of 22%, while *Fig. 3* indicates a lower value of 12%. In addition to the values calculated in the preceding sections, an important factor was considered and measured. This is the saturation component of I_{co} which was found to be 12 μa for the average of the four units. At 100°*C*, the saturation current would be approximately 2.4 milliamperes which is not considered excessive.

CONCLUSIONS

In this paper, a high temperature germanium transistor capable of operation to temperatures of 100°C without severe degradation of gain has been designed. In general, the correlation between design parameters and measured characteristics is good. The measured values of gain *vs.* temperature exhibit better characteristics than those calculated.

Marketing and Production Trends in the Semiconductor Industry

H. E. MARROWS*

A RECENT rule-of-thumb approximation of many marketing men in the transistor industry is that 0.5 transformers, 3 capacitors, 3 resistors and 1 socket are used for each transistor made and sold. This approximation will change, of course, with the growth of the industry. Taking only these major items and multiplying them by the millions of transistors sold gives one a good idea of the immense component market that is building up in the semiconductor field. In addition to these components, however, there are many others such as batteries, diodes, speakers, microphones, headphones and heat sink plates. The last mentioned item is relatively new, brought on by the sudden surge in the production of power transistors. United Aircraft Products, Inc. and the International Electronic Research Corporation both offer special aluminum configurations to dissipate heat in power transistors.

Because microminiaturization had been going on since World War II many components were readily adaptable to transistor circuits. However, components such as transformers, capacitors and transistor sockets had

*Author "Transistor Engineering Reference Handbook", published by John F. Rider, New York, N. Y.

Fig. 1—Typical transistor transformers made by Thermador Electrical Manufacturing Company

Fig. 2—Low cost adjustable inductors made for carrier applications in the range of 10kc to 100kc. (Courtesy Bell Telephone Laboratories)

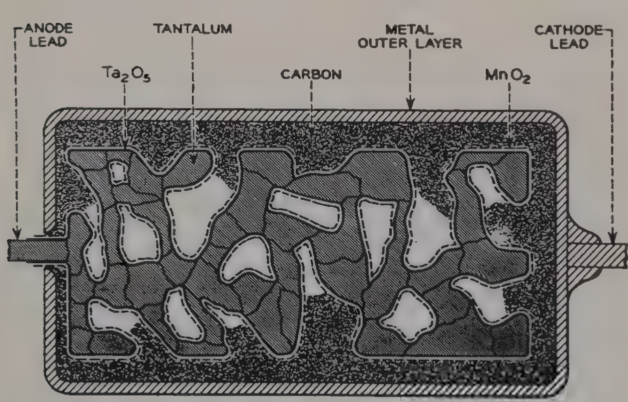

Fig. 3—The constructional features of a solid Electrolytic capacitor with tantalum anode (Courtesy Bell Telephone Laboratories)

to be designed specially for the new semiconductor circuitry. In these three categories over 25 companies are making transformers, over 20 are making special capacitors and 15 are making special clips or sockets.

Transformers

The demand for special transformers for transistors has been particularly great. *Fig. 1* shows typical units made by Thermador Electrical Manufacturing, while *Fig. 2* shows special variable inductors used in carrier applications. Transformer manufacturers now offer several hundred different types of transformers to meet all manner of impedance matching configurations. They have had to meet the transitions that have occurred in power levels (from 10 *mw* to 10 or more watts) and the higher frequency applications. However, they are obviously often a few steps behind the newer transistors—lacking right now, to some extent, transformer types suitable for the *u-h-f* frequencies.

Early applications of transistors were of the audio type, particularly in hearing aids, and the audio applications have continued to mount rapidly. As a result, most of the transformers available are in this range. Among the companies manufacturing these transformers are the following: Chicago Standard Transformer Corporation, Gramer-Halldorson Corporation, Triad Transformer Corporation, Wheeler Insulated Wire Company, Inc., Microtran Company, Inc., AS Danavox (Denmark), Audio Development Company, United Transformer Company, Thordarson-Meissner, Freed Transformer Company, and Epco Products, Inc.

Portable broadcast radios have, of course, used great quantities of transformers. Among the manufacturers of *r-f* transformers are the J. W. Miller Company and Superex Electronics Corporation. The *i-f* transformers are made by Vokar Corporation, the Automatic Manufacturing Corporation, Merit Coil Products Company, Inc., J. W. Miller Company, Radio Industries, Inc., Aladdin Electronics and Daystrom Instrument.

Transformers for pulse circuits and voltage conversion are becoming plentiful for many of the newer applications. Aladdin Electronics makes a great variety of blocking oscillator transformers as does Pulse Engineering. With servo circuits now rapidly becoming common, output transformers for these purposes are made in quantity by Frank Kessler Company, Inc., Daystrom Instrument, and Epco Products, Inc. Although some of the makers of voltage converter units use their own transformers, one company, Sunair Electronics, Inc., sells toroid transformers useful to 450 volts *d-c*. (40 watts continuous power).

Voltage conversion by transistors switches is considered by many as an application of great importance to the future of the electronics industry. The key to the conversion is a special transformer which converts *d-c* to *a-c* with efficiencies up to ninety per cent, but the operation of the inverter circuit depends primarily on the transformer core material.

Although many miniature capacitors made previous to the advent of the transistor fitted nicely into the new circuits, over twenty companies have made special efforts to meet semiconductor requirements. Tantalum types have captured the fancy of the designers, but other types are more economical and play an important role in the industry. Centralab, for example, makes ceramic disc types in a range of 0.1 *uf* to 2.2 *uf* at 3 volts *d-c*. These ultraminiature types are ideal for by-pass purposes and are considerably less expensive than electrolytic and tantalum types.

Tantalum capacitors, however, have brought many dividends to the designers, being available in a wide variety of capacity values as well as in voltage ratings. The most recent form of construction of the tantalum capacitor has been the solid anode type shown in Figs. 3 and 4. These can provide more capacity in a given space than any other type. Comparable to the size of the transistors themselves, these capacitors have low temperature characteristics, long shelf life and capacitance stability superior to other types of capacitors. These advantages are achieved by the substitution of the normal aqueous electrolyte by a solid semiconductor that will not leak, evaporate, freeze or corrode the oxide or metal layers.

In typical manufacture, this capacitor is built up, layer by layer, on the anode, a pellet of tiny particles sintered together at a very high temperature. The pellet is porous and consequently has a large surface area.

Among the companies manufacturing these solid tantalum capacitors are the following: Texas Instruments makes units from 25 *uf* at 35 volts to 200 *uf* at 6 volts; U. S. Electronics Development Corporation starts at 0.33 *uf* at 6-42 volts to 150 *uf* at 6 volts; Kemet Company offers a wide range of units starting with 1 *uf* at 30 volts (85°C) to 120 *uf* at 10 volts (85°C); IT&T Components Division offers units from 2 *uf* at 35 volts to 240 *uf* at 4 volts; Fansteel Metallurgical Corporation has units from 1 *uf* at 35 volts to 70 *uf* at 10 volts.

Some of the companies mentioned above also make foil type tantalum capacitors as well as the "wet" type with a porous anode using an electrolyte that is primarily a sulphuric acid solution. Ohmite Manufacturing Company makes a "wire" type which consists of a tantalum wire coil with specially processed oxide film which forms the anode, enclosed in an electrolyte solution. These Ohmite units have a capacity range of .01 to 80 *uf* in a variety of case sizes and voltage ratings. Some of the other companies making tantalum capacitors are: P. R. Mallory & Company, Inc., General Electric Company, and Sprague Electric Company.

By no means can other type electrolytic capacitors be overlooked for they have demonstrated excellent life in 15 or more years of continuous duty and they are economical. Companies making excellent types

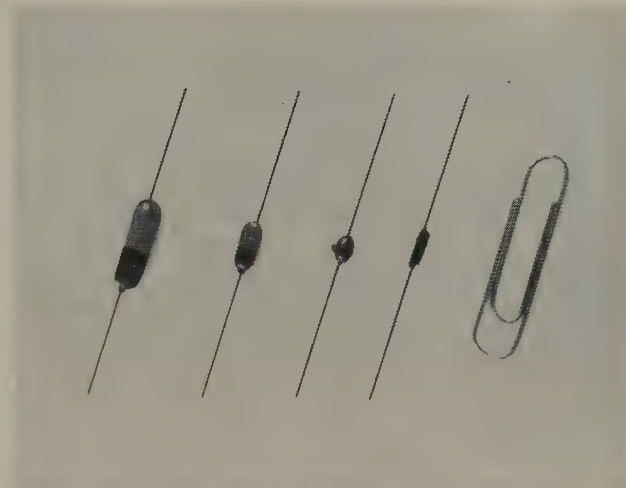

Fig. 4—Photographs of typical tantalum capacitors with solid anodes. The bottom unit is a type using coils of tantalum wire etched with hydrofluoric acid.

Fig. 5—Yardney Electric Corporation's Silvercel battery

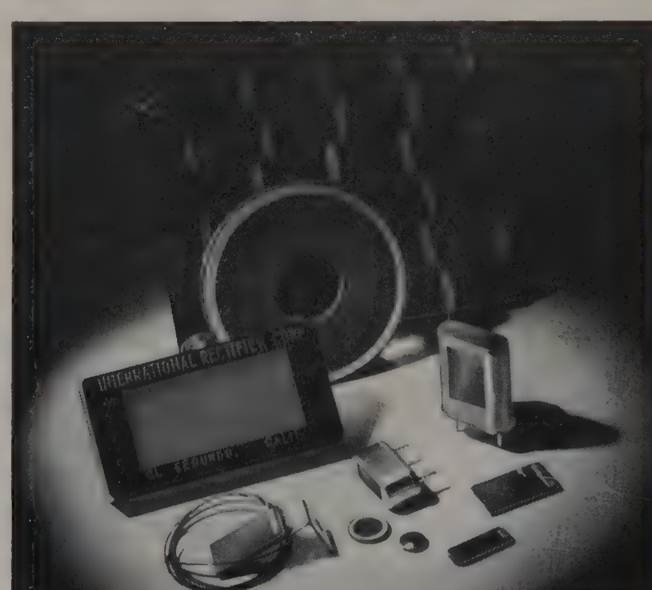

Fig. 6—International Rectifier Corporation's selenium cells and batteries.

other than tantalum are Aerovox Corporation, Barco, Inc., Illinois Condenser Company, and Pyramid Electric Company. Some of the companies which make the tantalums also make other types of capacitors.

Of course, capacitors other than electrolytics are needed. Mucon Corporation makes subminiature ceramic capacitors, Good-All Electric Manufacturing Company makes a wide selection of 50 volt miniature designs from .01 to .47 *uf*, while Radio Condenser Company and J. W. Miller Company make several variable tuning capacitors for the broadcast frequency range.

Miscellaneous Components

One of the components needed for every transistor is a socket or clip to hold it. Many varieties are made by a large number of manufacturers. Table I is a list of some companies that offer these mounts.

Although portable transistor radios will cut down the number of B batteries sold by the battery manufacturers, the use of batteries in other transistor applications, particularly portable instruments, will more than make up for this loss. Indeed, the advent of home radios with batteries appears to have good possibilities. Table II is a list of some manufacturers who are paying particular attention to the transistor market. Mercury batteries are finding favor with designers because of their long life and other favorable characteristics. Other types are being offered for special purposes or heavy duty, such as the Gulton rechargeable nickel cadmium Button-Cell Battery. Yardney's Silvercel, using silver and zinc as active materials, is shown in *Fig. 5*. Another Yardney battery called the Silverclad, along with the Silvercel, is widely used by the military for aircraft, guided missiles, underwater weapons and electronic equipment.

And one final word about batteries—the solar type. Two companies are now making them, the International Rectifier Corporation and the Semiconductor Division of Hoffman Electronics Corporation. Although both companies make the silicon type, IRC also makes some very economical selenium types, shown in *Fig. 6*. The author has found the latter to be very versatile for many unique applications.

Although other components to be mentioned are used to a lesser degree than those discussed, semiconductor diodes can appear in great quantities in some applications such as computers, power supplies and switching circuits. The number of companies making these is too great to list here and has appeared in a previous issue of Semiconductor Products. Because semiconductor diodes are used extensively in non-transistor circuits it is difficult to determine their role in the transistor field with any precise degree of accuracy. Nevertheless, the dollar value is large, the estimate being close to 20 million dollars in 1957. For 1958 it is estimated that the figure will be close to 40 million dollars.

Hearing aids as well as portable radio receivers account for many headphones. These are made by, among others, Knowles Electronics, Inc., Dyna-Empire, Inc. and Telex. Some of these companies also make microphones, great quantities of which are used in hearing aids. Tibbets Industries, Inc. is said to have made a million hearing aid microphones. Speakers are made by Jensen Manufacturing Company and Radio Corporation of America, among others.

At the present time the prominent applications of transistors outside the broadcast radio and hearing aid fields are in precision uses such as instrumentation. These precision uses call for high quality crystals and crystal ovens. Among the companies known in this field are: Electronics Division, Bulova Watch Company, Bliley Electric Company, Hill Electronic Engineering & Manufacturing Company, The James Knights Company, McCoy Electronics Company and Varo Manufacturing Company, Inc.

TABLE I

A List of Companies Making Sockets or Clips for Transistors

Atlas E-E Corporation
Augat Bros. Inc.
The Birtcher Corporation
Cinch Manufacturing Corporation
Elco Corporation
Electrical Industries, Div. of Amperex Electronic Corp.
Fluorocarbon Products Inc.
General Cement Manufacturing Co.
Grayhill, Inc.
Techron Corporation
Tinnerman Products, Inc.
Vector Electronic Co.

TABLE II

A List of Manufacturers Making Batteries Suitable for Transistor Circuits

Burgess Battery Company
Gould-National Batteries, Inc.
Gulton Industries, Inc., Alkaline Battery Division
International Rectifier Corporation
Mallory Battery Company
National Carbon Company
National Fabricated Products Div. of Hoffman Electronics Corp.
Ray-O-Vac Company
Yardney Electric Corporation

The Impact of the Transistor on the Electronics Industry

A history of transistors is typical of the impact of new discoveries. Their growth reaches into many allied fields and often changes the complexion of a big industry. The transistor and other semiconductors are being taken seriously by the electronics industry.

CHARACTERISTICS CHARTS of NEW DIODES and RECTIFIERS

SEMICONDUCTOR PRODUCTS follows up its tabulation of semiconductor devices with a list of newly-announced semiconductor diodes and rectifiers in a format useful to the engineer. This type of information will be released every 4 months. The current listing covers the period of January 15, 1958 through May 15, 1958. We have divided this material into 4 specific characteristics charts—Diodes and Rectifiers, Silicon Zener or Avalanche Diodes, Switching Diodes and Miscellaneous Diode Types—in order to provide the optimum presentation of the parameters describing these devices. In addition, a listing is provided for manufacturers who have announced that they have just begun supplying previously registered diodes and rectifiers. The characteristics of JETEC registered types are those supplied by the manufacturer of each registered type. *These charts are intended primarily as a guide; complete specifications, prices, and availability should be obtained directly from the manufacturers.*

MANUFACTURERS

(In Order of Code Letters)

AMP—	Amperex Electronic Corp.
AUD—	Audio Devices, Inc.
AUT—	Automatic Mfg. Co.
BEN—	Bendix Aviation Corp.
BER—	Berkshire Labs
BOG—	Bogue Electric Mfg. Co.
BOM—	Bomac Labs
BRA—	Bradley Labs
BTHB—	British Thomson-Houston Export Co., Ltd.
CBS—	CBS-Hytron
CTP—	Clevite Transistor Products, Inc.
CSF—	Compagnie Generale de T.S.F. (American Radio Co., Inc.)
EEVB—	English Electric Valve Co., Ltd.
FAN—	Fansteel Metallurgical Corp.
GAH—	Gahagan, Inc.
GECB—	General Electric Co., Ltd.
GE—	General Electric Company, Semiconductor Div.
GTC—	General Transistor Corp.
HSD—	Hoffman Semiconductor Division
HUG—	Hughes Products Division
IFHS—	Institutet for Halvledarforskning
INRC—	International Rectifier Corp.
IRC—	International Resistance Co.
ITT—	International Tel. & Tel. Corp.
KEM—	Kemtron Electron Products, Inc.
LCTF—	Laboratoire Central de Telecommunications
MIC—	Microwave Associates, Inc.
MOT—	Motorola, Inc.
MUL—	Mullard, Ltd.
NPC—	Nucleonic Products Co., Inc.
PHI—	Philco Corp., Lansdale Tube Company
PSI—	Pacific Semiconductors, Inc.
QSC—	Qutronic Semiconductor Corp.
RAY—	Raytheon Manufacturing Company
RCA—	Radio Corporation of America, Semiconductor Div.
RRC—	Radio Receptor Co., Inc.
SAR—	Sarkes Tarzian, Inc., Rectifier Division
SSL—	Shockley Semiconductor Lab, Backman Instruments, Inc.
SIE—	Siemens & Halske Aktiengesellschaft
SSD—	Sperry Semiconductor Division
STCB—	Standard Telephone & Cables, Ltd. (Intelex Systems)
SYL—	Sylvania Electric Products, Inc.
TFKG—	Telefunken, Ltd.
THE—	Thermosen, Inc.
TI—	Texas Instruments, Inc.
TKD—	Tekade, Nurnberg, Germany
TOK—	Tokyo Tsushin Kogyo, Ltd.
TRA—	Transitron Electronic Corp.
TSC—	Trans-Sil Corp.
USD—	United States Dynamics Corp.
USS—	U. S. Semiconductor Products, Inc.
WEC—	Western Electric Co.
WEST—	Westinghouse Electric Corp.

CHARACTERISTICS CHART of DIODES and RECTIFIERS

TYPE NO.	USE (See Code Below)	MAT	PIV (volts)	MAX. CONT. WORK. VOLT. (volts)	Min. Forward Current @ 25°C I_f @ E_f (mA) (volts)	MAX. D.C. OUTPUT CURRENT[4] @ T (°C) (amps)	MAX. FULL LOAD VOLT. DROP[4] (volts)	Max. Rev. Current I_b @ E_b @ T (uA) (volts) (°C)	MFR. (See code at start of charts)
1N66A	1	Ge	70	60	5.0 @ 1.0	.030 @ 25		800 @ 50 @ 25	RAY
1N294A	1	Ge	70	60	5.0 @ 1.0	.035 @ 25		800 @ 50 @ 25	RAY
1N297A	1	Ge	100	80	3.5 @ 1.0	.035 @ 25		100 @ 50 @ 25	RAY
1N298A	1	Ge	85	70	3.5 @ 1.0	.035 @ 25		800 @ 50 @ 25	RAY
1N316A	1	Si	50	50		.25 @ 100A	.60	10 @ 50 @ 100A	BOG
1N317A	1	Si	100	100		.25 @ 100A	.60	10 @ 100 @ 100A	BOG
1N318A	1	Si	200	200		.25 @ 100A	.60	15 @ 200 @ 100A	BOG
1N319A	1	Si	350	350		.25 @ 100A	.60	40 @ 350 @ 100A	BOG
1N320A	1	Si	500	500		.25 @ 100A	.60	40 @ 500 @ 100A	BOG
1N321A	1	Si	850	850		.25 @ 100A	.60	60 @ 850 @ 100A	BOG
1N322A	1	Si	1000	1000		.25 @ 100A	.60	60 @ 1000 @ 100A	BOG
1N323A	1	Si	50	50		.40 @ 100A	.60	10 @ 50 @ 100A	BOG
1N324A	1	Si	100	100		.40 @ 100A	.60	10 @ 100 @ 100A	BOG
1N325A	1	Si	200	200		.40 @ 100A	.60	16 @ 200 @ 100A	BOG
1N326A	1	Si	350	350		.40 @ 100A	.60	40 @ 350 @ 100A	BOG
1N327A	1	Si	500	500		.40 @ 100A	.60	40 @ 500 @ 100A	BOG
1N328A	1	Si	850	850		.40 @ 100A	.60	60 @ 850 @ 100A	BOG
1N329A	1	Si	1000	1000		.40 @ 100A	.60	60 @ 1000 @ 100A	BOG
1N501	1		100	80	100 @ 1.0			40 @ 80 @ 25	CBS
1N502	1		125	100	100 @ 1.0			40 @ 100 @ 25	CBS
1N673	1	Si	350	350		.40 @ 25	1.0	.30 @ 300 @ 25	WEC
1N1124	1	Si	200	200	1000 @ 1.1	3.0 @ 50		10 @ 200 @ 25	TI
1N1125	1	Si	300	300	1000 @ 1.1	3.0 @ 50		10 @ 300 @ 25	TI
1N1126	1	Si	400	400	1000 @ 1.1	3.0 @ 50		10 @ 400 @ 25	TI
1N1127	1	Si	500	500	1000 @ 1.1	3.0 @ 50		10 @ 500 @ 25	TI
1N1124R	1	Si	200	200	1000 @ 1.1	3.0 @ 50		10 @ 200 @ 25	TI
1N1125R	1	Si	300	300	1000 @ 1.1	3.0 @ 50		10 @ 300 @ 25	TI
1N1126R	1	Si	400	400	1000 @ 1.1	3.0 @ 50		10 @ 400 @ 25	TI
1N1127R	1	Si	500	500	1000 @ 1.1	3.0 @ 50		10 @ 500 @ 25	TI
1N1128	1	Si	600	600	1000 @ 1.1	3.0 @ 50		10 @ 600 @ 25	TI
1N1128R Reverse polarity version of 1N1128									
1N1414	1,2	Si	350	350		100 @ 25	1.25		WEC
1N1415	1,2	Si	350	350		10 @ 25	1.1		WEC
1N1434	2	Si	50		60A @ 1.2	30 @ 135		5000 @ 50 @ 150	BEN
1N1435	2	Si	100		60A @ 1.2	30 @ 135		5000 @ 100 @ 150	BEN
1N1436	2	Si	200		60A @ 1.2	30 @ 135		5000 @ 200 @ 150	BEN
1N1437	2	Si	400		60A @ 1.2	30 @ 135		5000 @ 400 @ 150	BEN
1N1438	2	Si	600		60A @ 1.2	30 @ 135		5000 @ 600 @ 150	BEN
1N1563	2	Si	100	100	1000 @ 1.2	1.0 @ 25	1.5	50 @ 100 @ 25	MOT
1N1564	2	Si	200	200	1000 @ 1.2	1.0 @ 25	1.5	50 @ 200 @ 25	MOT
1N1565	2	Si	300	300	1000 @ 1.2	1.0 @ 25	1.5	50 @ 300 @ 25	MOT
1N1566	2	Si	400	400	1000 @ 1.2	1.0 @ 25	1.5	50 @ 400 @ 25	MOT
1N1567	2	Si	500	500	1000 @ 1.2	1.0 @ 25	1.5	50 @ 500 @ 25	MOT
1N1568	2	Si	600	600	1000 @ 1.2	1.0 @ 25	1.5	50 @ 600 @ 25	MOT
1N1569	2	Si	100	100	1000 @ 1.2	1.0 @ 25	1.5	5.0 @ 100 @ 25	MOT
1N1570	2	Si	200	200	1000 @ 1.2	1.0 @ 25	1.5	5.0 @ 200 @ 25	MOT
1N1571	2	Si	300	300	1000 @ 1.2	1.0 @ 25	1.5	5.0 @ 300 @ 25	MOT
1N1572	2	Si	400	400	1000 @ 1.2	1.0 @ 25	1.5	5.0 @ 400 @ 25	MOT
1N1575	2	Si	100	100	1000 @ 1.2	3.5 @ 25	1.5	5.0 @ 100 @ 25	MOT
1N1576	2	Si	200	200	1000 @ 1.2	3.5 @ 25	1.5	5.0 @ 200 @ 25	MOT
1N1577	2	Si	300	300	1000 @ 1.2	3.5 @ 25	1.5	5.0 @ 300 @ 25	MOT
1N1578	2	Si	400	400	1000 @ 1.2	3.5 @ 25	1.5	5.0 @ 400 @ 25	MOT
1N1612	2	Si	50		10A @ 1.5	5.0 @ 135		1000 @ 50 @ 150	BEN
1N1613	2	Si	100		10A @ 1.5	5.0 @ 135		1000 @ 100 @ 150	BEN
1N1614	2	Si	200		10A @ 1.5	5.0 @ 135		1000 @ 200 @ 150	BEN
1N1615	2	Si	400		10A @ 1.5	5.0 @ 135		1000 @ 400 @ 150	BEN
1N1616	2	Si	600		10A @ 1.5	5.0 @ 135		1000 @ 600 @ 150	BEN
1N1617	2	Si	100			1.5 @ 100	1.25	5000 @ 100 @ 25	SAR
1N1618	2	Si	200			1.5 @ 100	1.25	5000 @ 200 @ 25	SAR
1N1619	2	Si	300			1.5 @ 100	1.25	2500 @ 300 @ 25	SAR
1N1620	2	Si	400			1.5 @ 100	1.25	2500 @ 400 @ 25	SAR
1N1621	2	Si	100			10 @ 100	1.25	5000 @ 100 @ 25	SAR
1N1622	2	Si	200			10 @ 100	1.25	5000 @ 200 @ 25	SAR
1N1623	2	Si	300			10 @ 100	1.25	2500 @ 300 @ 25	SAR
1N1624	2	Si	400			10 @ 100	1.25	2500 @ 400 @ 25	SAR
1N1692	1	Si	100	100		.250 @ 100A	.60	500 @ 100 @ 100A	GE
1N1693	1	Si	200	200		.250 @ 100A	.60	500 @ 100 @ 100A	GE
1N1694	1	Si	300	300		.250 @ 100A	.60	500 @ 100 @ 100A	GE
1N1695	1	Si	400	400		.250 @ 100A	.60	500 @ 100 @ 100A	GE
1N1701	1	Si	50	50	1000 @ 1.7	.150 @ 100A		400 @ 50 @ 100[4]	INRC
1N1702	1	Si	100	100	1000 @ 1.7	.150 @ 100A		400 @ 100 @ 100[4]	INRC
1N1703	1	Si	200	200	1000 @ 1.7	.150 @ 100A		300 @ 200 @ 100[4]	INRC
1N1704	1	Si	300	300	1000 @ 1.7	.150 @ 100A		300 @ 300 @ 100[4]	INRC

NOTATIONS

Under Use

1. General Purpose
2. Power Rectifier
3. Magnetic Ampilfier

Other

4. For half wave resistive load average over 1 cycle

Under Reverse Current

5. Dynamic

Under Mfr.

6. Available in stack form from that manufacturer

Following any temperature reading these symbols apply

A — Ambient
C — Case
J — Junction
S — Storage
* — Forced Convection — 2000LFM

Manufacturers should be contacted for value and test condition for surge current and maximum peak recurrent current.

CHARACTERISTICS CHART of DIODES and RECTIFIERS

TYPE NO.	USE (See Code Below)	MAT	PIV (volts)	MAX. CONT. WORK. VOLT. (volts)	Min. Forward Current @ 25°C I_f @ E_f (mA) (volts)	MAX. D.C. OUTPUT CURRENT[4] @ T (°C) (amps)	MAX. FULL LOAD VOLT. DROP[4] (volts)	Max. Rev. Current I_b @ E_b @ T (uA) (volts) (°C)	MFR. (See code at start of charts)
1N1705	1	Si	400	400	1000 @ 1.7	.150 @ 100A		300 @ 400 @ 100[4]	INRC
1N1706	1	Si	500	500	1000 @ 1.7	.150 @ 100A		300 @ 400 @ 100[4]	INRC
1N1707	1	Si	50	50	1000 @ 1.3	.175 @ 150A		400 @ 60 @ 150[4]	INRC
1N1708	1	Si	100	100	1000 @ 1.3	.175 @ 150A		400 @ 100 @ 150[4]	INRC
1N1709	1	Si	200	200	1000 @ 1.3	.175 @ 150A		300 @ 200 @ 150[4]	INRC
1N1710	1	Si	300	300	1000 @ 1.3	.175 @ 150A		300 @ 300 @ 150[4]	INRC
1N1711	1	Si	400	400	1000 @ 1.3	.175 @ 150A		300 @ 400 @ 150[4]	INRC
1N1712	1	Si	500	500	1000 @ 1.3	.125 @ 150A		300 @ 500 @ 150[4]	INRC
1N1730		Si	1000	1000	100 @ 5	200 @ 25		10 @ 1000 @ 25	PSI
1N1731		Si	1500	1500	100 @ 5	200 @ 25		10 @ 1500 @ 25	PSI
1N1732		Si	2000	2000	100 @ 9	200 @ 25		10 @ 2000 @ 25	PSI
1N1733		Si	3000	3000	100 @ 12	150 @ 25		10 @ 3000 @ 25	PSI
1N1734		Si	5000	5000	100 @ 18	100 @ 25		10 @ 5000 @ 25	PSI
1SJ60A	1	Si	600	600		.10 @ 100A	.60	60 @ 600 @ 100A	BOG
2SJ60A	1	Si	600	600		.25 @ 100A	.60	60 @ 600 @ 100A	BOG
4SJ60A	1	Si	600	600		.40 @ 100A	.60	60 @ 600 @ 100A	BOG
25H5	2	Si	50			25 @ 25#	.90	10ma @ 50 @ 175	INRC
25H10	2	Si	100			25 @ 25#	.90	10ma @ 100 @ 175	INRC
25H15	2	Si	150			25 @ 25#	.90	10ma @ 150 @ 175	INRC
25H20	2	Si	200			25 @ 25#	.90	10ma @ 200 @ 175	INRC
25H25	2	Si	250			25 @ 25#	.90	10ma @ 250 @ 175	INRC
25H30	2	Si	300			25 @ 25#	.90	10ma @ 300 @ 175	INRC
25H35	2	Si	350			25 @ 25#	.90	10ma @ 350 @ 175	INRC
25H40	2	Si	400			25 @ 25#	.90	10ma @ 400 @ 175	INRC
25H45	2	Si	450			25 @ 25#	.90	10ma @ 450 @ 175	INRC
25H50	2	Si	500			25 @ 25#	.90	10ma @ 500 @ 175	INRC
AM1	2	Si	50			1.0 @ 100		300 @ 50 @ 100	AUT
AM2	2	Si	50			.40 @ 100		300 @ 50 @ 100	AUT
AM3	2	Si	50			.20 @ 100		300 @ 50 @ 100	AUT
AM4	2	Si	50			1.0 @ 150		500 @ 50 @ 100	AUT
AM5	2	Si	50			.40 @ 150		500 @ 50 @ 100	AUT
AM11	2	Si	100			1.0 @ 150		300 @ 100 @ 100	AUT
AM12	2	Si	100			.40 @ 100		300 @ 100 @ 100	AUT
AM13	2	Si	100			.20 @ 100		300 @ 100 @ 100	AUT
AM21	2	Si	200			1.0 @ 100		300 @ 200 @ 100	AUT
AM22	2	Si	200			.40 @ 100		300 @ 200 @ 100	AUT
AM23	2	Si	200			.20 @ 100		300 @ 200 @ 100	AUT
AM24	2	Si	200			1.0 @ 150		500 @ 200 @ 150	AUT
AM31	2	Si	300			1.0 @ 100		300 @ 300 @ 100	AUT
AM32	2	Si	300			.40 @ 100		300 @ 300 @ 100	AUT
AM33	2	Si	300			.20 @ 100		300 @ 300 @ 100	AUT
AM34	2	Si	300			1.0 @ 150		500 @ 300 @ 150	AUT
AM41	2	Si	400			1.0 @ 100		300 @ 400 @ 100	AUT
AM42	2	Si	400			.40 @ 100		300 @ 400 @ 100	AUT
AM43	2	Si	400			.20 @ 100		300 @ 400 @ 100	AUT
AM44	2	Si	400			1.0 @ 150		500 @ 400 @ 150	AUT
AM51	2	Si	500			1.0 @ 100		300 @ 500 @ 100	AUT
AM52	2	Si	500			.40 @ 100		300 @ 500 @ 100	AUT
AM53	2	Si	500			.20 @ 100		300 @ 500 @ 100	AUT
AM54	2	Si	500			1.0 @ 150		500 @ 500 @ 150	AUT
AM55	2	Si	500			.40 @ 150		500 @ 500 @ 150	AUT
AM56	2	Si	500			.20 @ 150		500 @ 500 @ 150	AUT
AM61	2	Si	600			1.0 @ 100		300 @ 600 @ 100	AUT
AM62	2	Si	600			.40 @ 100		300 @ 600 @ 100	AUT
AM63	2	Si	600			.20 @ 100		300 @ 600 @ 100	AUT
AM64	2	Si	600			1.0 @ 150		500 @ 600 @ 150	AUT
AM65	2	Si	600			.40 @ 150		500 @ 600 @ 150	AUT
AM66	2	Si	600			.20 @ 150		500 @ 600 @ 150	AUT
AM4005	2	Si	400			5.0 @ 135		5000 @ 400 @ 135	AUT
AM4010	2	Si	400			10 @ 135		5000 @ 400 @ 135	AUT
AM4020	2	Si	400			20 @ 135		5000 @ 400 @ 135	AUT
B200	2	Si	360			.20 @ 25	2.0	4000 @ 360 @ 25	AUD
CF1B10M	2	Si	1500			.30 @ 75*	15	25 @ 1500 @ 25	INRC
CF1B12M	2	Si	1800			.27 @ 75*	18	25 @ 1800 @ 25	INRC
CF1B16M	2	Si	2400			.22 @ 75*	24	25 @ 2400 @ 25	INRC
CTP462	1	Ge	55	45	150 @ 1.0			5.0 @ 10 @ 25	CTP
CTP573	1	Ge	6	2	1.0 @ .30 } 100 @ 1.0 }				CTP
CTP591	1	Ge	10	6	1.4 @ 3.0			4.0 @ 3 @ 25	CTP
CTP592	1	Ge	60	50	1.4 @ .30				CTP
CTP2303	1	Si	150		20 @ 1.5			20 @ 100 @ 100	CTP
CTP2313	1	Si	150	130	5.0 @ 1.5			20 @ 125 @ 100	CTP
CTP2315	1	Si	40	36	5.0 @ 1.5			20 @ 30 @ 100	CTP
CTP2317	1	Si	200	180	5.0 @ 1.5			50 @ 175 @ 100	CTP
CTP2321	1	Si	60		75 @ 1.0			20 @ 50 @ 150	CTP
CTP2340	1	Si		2	1.0 @ .64 } 100 @ 1.0 }				
D5	2	Si	50			400 @ 25	1.0	1000 @ 50 @ 25	TSC[6]
D10	2	Si	100			400 @ 25	1.0	1000 @ 100 @ 25	TSC[6]
D15	2	Si	150			400 @ 25	1.0	1000 @ 150 @ 25	TSC[6]
D20	2	Si	200			400 @ 25	1.0	1000 @ 200 @ 25	TSC[6]
D25	2	Si	250			400 @ 25	1.0	1000 @ 250 @ 25	TSC[6]
D30	2	Si	300			400 @ 25	1.0	1000 @ 300 @ 25	TSC[6]
D35	2	Si	350			400 @ 25	1.0	1000 @ 350 @ 25	TSC[6]

CHARACTERISTICS CHART of DIODES and RECTIFIERS

TYPE NO.	USE (See Code Below)	MAT	PIV (volts)	MAX. CONT. WORK. VOLT. (volts)	Min. Forward Current @ 25°C I_f @ E_f (mA) (volts)	MAX. D.C. OUTPUT CURRENT[4] @ T (°C) (amps)	MAX. FULL LOAD VOLT. DROP[4] (volts)	Max. Rev. Current I_b @ E_b @ T (uA) (volts) (°C)	MFR. (See code at start of charts)
DF1C18M	2	Si	3600			.29 @ 75*	27	25 @ 3600 @ 25	INRC
DF1C24M	2	Si	4800			.23 @ 75*	36	25 @ 4800 @ 25	INRC
DF1C30M	2	Si	6000			.21 @ 75*	45	25 @ 6000 @ 25	INRC
DF1D36M	2	Si	7200			.24 @ 75*	54	25 @ 7200 @ 25	INRC
DF1D40M	2	Si	8000			.22 @ 75*	60	25 @ 8000 @ 25	INRC
EF1A5M	2	Si	1500			.36 @ 75*	7.5	25 @ 1500 @ 25	INRC
EF1A6M	2	Si	1800			.33 @ 75*	9	25 @ 1800 @ 25	INRC
EF1A8M	2	Si	2400			.27 @ 75*	12	25 @ 2400 @ 25	INRC
EF1B12M	2	Si	3600			.28 @ 75*	18	25 @ 3600 @ 25	INRC
EF1B16M	2	Si	4800			.22 @ 75*	24	25 @ 4800 @ 25	INRC
EF1C20M	2	Si	6000			.28 @ 75*	30	25 @ 6000 @ 25	INRC
EF1C24M	2	Si	7200			.23 @ 75*	36	25 @ 7200 @ 25	INRC
EF1D40M	2	Si	12000			.22 @ 75*	60	25 @ 12000 @ 25	INRC
FF1D35M	2	Si	14000			.24 @ 75*	52	25 @ 14000 @ 25	INRC
FF1D40M	2	Si	16000			.22 @ 75*	60	25 @ 16000 @ 25	INRC
G45D	1	Ge	10	10	5.0 @ 1.0			25 @ 2 @ 25	GAH
G49	1	Ge	50	30	15 @ 1.0			200 @ 24 @ 50	GAH
G98	1	Ge	60	50	100 @ 1.0			500 @ 100 @ 25	GAH
G106	1	Ge	200	200	100 @ 1.0			600 @ 200 @ 25	GAH
G5/62	1	Ge	75	60	5.0 @ 1.0	.03 @ 45		20 @ 10 @ 60	TKD
GSD5/62	1	Ge	75	60	5.0 @ 1.0	.03 @ 45		20 @ 10 @ 60	TKD
GTD970	1	Ge	100	80	400 @ 1.0			25 @ 50 @ 25	GTC
GTD971	1	Ge	100	80	200 @ 1.0			25 @ 50 @ 25	GTC
GTD972	1	Ge	100	80	100 @ 1.0			25 @ 50 @ 25	GTC
GTD973	1	Ge	80	70	200 @ 1.0			50 @ 50 @ 25	GTC
GTD974	1	Ge	80	70	100 @ 1.0			50 @ 50 @ 25	GTC
GTD975	1	Ge	75	65	200 @ 1.0			100 @ 50 @ 25	GTC
GTD976	1	Ge	75	65	100 @ 1.0			100 @ 50 @ 25	GTC
GTD977	1	Ge	70	60	200 @ 1.0			250 @ 50 @ 25	GTC
GTD978	1	Ge	70	60	100 @ 1.0			250 @ 50 @ 25	GTC
GTD979	1	Ge	70	60	100 @ 1.0			500 @ 50 @ 25	GTC
GTD980	1	Ge	30	15	50 @ 1.0			500 @ 10 @ 25	GTC
HD6751	1,3	Si	200	175	100 @ 1.0			.10 @ 150 @ 25	HUG
HD6752	1,3	Si	250	225	100 @ 1.0			.10 @ 200 @ 25	HUG
HD6753	1,3	Si	300	275	100 @ 1.0			.10 @ 250 @ 25	HUG
HD6754	1,3	Si	350	325	100 @ 1.0			.10 @ 300 @ 25	HUG
HD6755	1,3	Si	400	375	100 @ 1.0			.10 @ 350 @ 25	HUG
HD6763	1,3	Si	80	70	200 @ 1.0			30 @ 60 @ 150	HUG
HD6765	1,3	Si	150	130	200 @ 1.0			30 @ 125 @ 150	HUG
HD6767	1,3	Si	200	180	200 @ 1.0			30 @ 175 @ 150	HUG
HD6769	1,3	Si	250	225	200 @ 1.0			50 @ 225 @ 150	HUG
HD6772	1,3	Si	350	300	200 @ 1.0			50 @ 300 @ 150	HUG
HD6774	1,3	Si	420	380	200 @ 1.0			50 @ 380 @ 150	HUG
HD6777	1,3	Si	40	36	200 @ 1.0			30 @ 30 @ 150	HUG
HR10313	2	Si	700	675		.30 @ 25	.50	20	HUG
HR10314	2	Si	800	775		.30 @ 25	.50	20	HUG
HR10315	2	Si	900	875		.30 @ 25	.50	20	HUG
HR10316	2	Si	1000	975		.30 @ 25	.50	20	HUG
HR10422	2	Si	100			.350 @ 100		100 @ 100 @ 25	HUG
HR10423	2	Si	200			.350 @ 100		100 @ 200 @ 25	HUG
HR10424	2	Si	300			.350 @ 100		100 @ 300 @ 25	HUG
HR10425	2	Si	400			.350 @ 100		100 @ 400 @ 25	HUG
HR10671	2	Si	100			3.0 @ 150		500 @ 100 @ 25	HUG
HR10673	2	Si	200			3.0 @ 150		500 @ 200 @ 25	HUG
HR10675	2	Si	300			3.0 @ 150		500 @ 300 @ 25	HUG
HR10677	2	Si	400			3.0 @ 150		500 @ 400 @ 25	HUG
HR10679	2	Si	500			2.0 @ 135		500 @ 500 @ 25	HUG
HR10681	2	Si	600			2.0 @ 135		500 @ 600 @ 25	HUG
K5/2	1	Ge	30	25	5.0 @ 1.0			45 @ 3 @ 25	TKD
K5/4	1	Ge	45	40	5.0 @ 1.0			800 @ 30 @ 25	TKD
K5/6	1	Ge	75	60	5.0 @ 1.0			30 @ 10 @ 25	TKD
K5/62	1	Ge	75	60	5.0 @ 1.0			20 @ 10 @ 60	TKD
LDS20	2	Si	200	200		60 @ 150C	.42	10ma @ 200 @ 190J	BOG
LDS30	2	Si	300	300		60 @ 150C	.42	10ma @ 300 @ 190J	BOG
LDS40	2	Si	400	400		60 @ 150C	.42	10ma @ 400 @ 190J	BOG
OA174	1	Ge	70	55	4.0 @ 1.0			250 @ 50 @ 25	TFKG
OY1	1	Ge	200	100	50 @ .50	.10 @ 45		250 @ 250 @ 25	TKD
PR50	3	Si	50		1000 @ 1.0	5.0 @ 25	2.0	10 @ 50 @ 25	USS
PR600	3	Si	600		1000 @ 1.0	4.0 @ 25	2.0	10 @ 600 @ 25	USS
PR700	3	Si	700		1000 @ 1.0	4.0 @ 25	2.0	10 @ 700 @ 25	USS
PR800	3	Si	800		1000 @ 1.0	4.0 @ 25	2.0	10 @ 800 @ 25	USS
PR900	3	Si	900		1000 @ 1.0	3.0 @ 25	2.0	10 @ 900 @ 25	USS
R5	2	Si	50			1.0 @ 25	1.0	20 @ 50 @ 25	TSC[6]
R10	2	Si	100			1.0 @ 25	1.0	20 @ 100 @ 25	TSC[6]
R20	2	Si	200			1.0 @ 25	1.0	20 @ 200 @ 25	TSC[6]
R30	2	Si	300			1.0 @ 25	1.0	20 @ 300 @ 25	TSC[6]
R40	2	Si	400			1.0 @ 25	1.0	20 @ 400 @ 25	TSC[6]
R50	2	Si	500			1.0 @ 25	1.0	20 @ 500 @ 25	TSC[6]
R60	2	Si	600			1.0 @ 25	1.0	20 @ 500 @ 25	TSC[6]
RR50	1	Si	50		1000 @ 1.0	5.0 @ 25	2.0	1000 @ 50 @ 25	USS
RR100	1	Si	100		1000 @ 1.0	5.0 @ 25	2.0	1000 @ 100 @ 25	USS
RR200	1	Si	200		1000 @ 1.0	5.0 @ 25	2.0	1000 @ 200 @ 25	USS
RR300	1	Si	300		1000 @ 1.0	5.0 @ 25	2.0	1000 @ 300 @ 25	USS
RR400	1	Si	400		1000 @ 1.0	5.0 @ 25	2.0	1000 @ 400 @ 25	USS
RR500	1	Si	500		1000 @ 1.0	4.0 @ 25	2.0	1000 @ 500 @ 25	USS

CHARACTERISTICS CHART of DIODES and RECTIFIERS

TYPE NO.	USE {See Code Below}	MAT	PIV (volts)	MAX. CONT. WORK. VOLT. (volts)	Min. Forward Current @ 25°C I_f @ E_f (mA) (volts)	MAX. D.C. OUTPUT CURRENT[4] @ T (°C) (amps)	MAX. FULL LOAD VOLT. DROP[4] (volts)	Max. Rev. Current I_b @ E_b @ T (uA) (volts) (°C)	MFR. {See code at start of charts}
S5	2	Si	50			5.0 @ 25	1.0	20 @ 50 @ 25	TSC[6]
S10	2	Si	100			5.0 @ 25	1.0	20 @ 100 @ 25	TSC[6]
S20	2	Si	200			5.0 @ 25	1.0	20 @ 200 @ 25	TSC[6]
S30	2	Si	300			5.0 @ 25	1.0	20 @ 300 @ 25	TSC[6]
S40	2	Si	400			5.0 @ 25	1.0	20 @ 400 @ 25	TSC[6]
S50	2	Si	500			5.0 @ 25	1.0	20 @ 500 @ 25	TSC[6]
S60	2	Si	600			5.0 @ 25	1.0	20 @ 600 @ 25	TSC[6]
SD91	1	Si	100	100	550 @ 1.5	.300 @ 100A		1000 @ 100 @ 100	INRC
SD91A	1	Si	100	100	750 @ 1.3	.500 @ 100A		500 @ 100 @ 100	INRC
SD92	1	Si	200	200	550 @ 1.5	.300 @ 100A		1000 @ 200 @ 100	INRC
SD92A	1	Si	200	200	750 @ 1.3	.500 @ 100A		500 @ 200 @ 100	INRC
SD93	1	Si	300	300	550 @ 1.5	.300 @ 100A		1000 @ 300 @ 100	INRC
SD93A	1	Si	300	300	750 @ 1.3	.500 @ 100A		500 @ 300 @ 100	INRC
SD94	1	Si	400	400	550 @ 1.5	.300 @ 100A		400 @ 400 @ 100	INRC
SD94A	1	Si	400	400	750 @ 1.3	.500 @ 100A		100	INRC
SD95	1	Si	500	500	550 @ 1.5	.300 @ 100A		650 @ 500 @ 100	INRC
SD95A	1	Si	500	500	750 @ 1.3	.400 @ 100A		300 @ 400 @ 100	INRC
SR101	2,3	Si	50	50		.50 @ 25A	1.5	300 @ 50 @ 150A	GTC
SR102	2,3	Si	100	100		.100 @ 25A	1.5	300 @ 100 @ 150A	GTC
SR103	2,3	Si	100	100		.200 @ 25A	1.5	300 @ 100 @ 150A	GTC
SR104	2,3	Si	100	100		.750 @ 25A	1.5	300 @ 100 @ 150A	GTC
SR105	2,3	Si	200	200		.200 @ 25A	1.5	300 @ 200 @ 150A	GTC
SR106	2,3	Si	200	200		.400 @ 25A	1.5	300 @ 200 @ 150A	GTC
SR107	2,3	Si	200	200		.750 @ 25A	1.5	300 @ 200 @ 150A	GTC
SR108	2,3	Si	400	400		.100 @ 25A	1.5	300 @ 400 @ 150A	GTC
SR109	2,3	Si	400	400		.400 @ 25A	1.5	300 @ 400 @ 150A	GTC
SR110	2,3	Si	600	600		.200 @ 25A	1.5	300 @ 600 @ 150A	GTC
SR111	2,3	Si	600	600		.750 @ 25A	1.5	300 @ 600 @ 150A	GTC
SR112	2,3	Si	1000	1000		.750 @ 25A	1.5	300 @ 1000 @ 150A	GTC
SX641	1,2,3	Si	60	60	100 @ 1.5	.20 @ 80	2.0	5.0 @ 60 @ 100	GECB
SX642	1,2,3	Si	120	120	100 @ 1.5	.20 @ 70	2.0	5.0 @ 120 @ 100	GECB
SX643	1,2,3	Si	180	180	100 @ 1.5	.20 @ 65	2.0	15 @ 180 @ 100	GECB
SX644	1,2,3	Si	300	300	100 @ 1.5	.20 @ 40	2.0	15 @ 300 @ 100	GECB
SX645	1,2,3	Si	400	400	100 @ 1.5	.20 @ 30	2.0	15 @ 400 @ 100	GECB
T5	2	Si	50			10 @ 25	1.0	20 @ 50 @ 25	TSC[6]
T10	2	Si	100			10 @ 25	1.0	20 @ 100 @ 25	TSC[6]
T20	2	Si	200			10 @ 25	1.0	20 @ 200 @ 25	TSC[6]
T30	2	Si	300			10 @ 25	1.0	20 @ 300 @ 25	TSC[6]
T40	2	Si	400			10 @ 25	1.0	20 @ 400 @ 25	TSC[6]
T50	2	Si	500			10 @ 25	1.0	20 @ 500 @ 25	TSC[6]
T60	2	Si	600			10 @ 25	1.0	20 @ 500 @ 25	TSC[6]
TM86	2	Si	800	560		.20 @ 125	2.0	500 @ 800 @ 125	TRA
TM106	2	Si	1000	700		.20 @ 125	2.0	500 @ 1000 @ 125	TRA
TM124	2	Si	1200	840		1.0 @ 125	2.0	500 @ 1200 @ 125	TRA
TM125	2	Si	1200	840		.40 @ 125	2.0	500 @ 1200 @ 125	TRA
TM126	2	Si	1200	840		.20 @ 125	2.0	500 @ 1200 @ 125	TRA
U5	2	Si	50			100 @ 25	1.0	250 @ 50 @ 25	TSC[6]
U10	2	Si	100			100 @ 25	1.0	250 @ 100 @ 25	TSC[6]
U20	2	Si	200			100 @ 25	1.0	250 @ 200 @ 25	TSC[6]
U30	2	Si	300			100 @ 25	1.0	250 @ 300 @ 25	TSC[6]
U40	2	Si	400			100 @ 25	1.0	250 @ 400 @ 25	TSC[6]
USD142B	3	Si	100	100	1000 @ 1.0	5.0 @ 25	1.5	200 @ 100 @ 25	USD
USD142D	3	Si	200	200	1000 @ 1.0	5.0 @ 25	1.5	200 @ 200 @ 25	USD
USD142F	3	Si	300	300	1000 @ 1.0	5.0 @ 25	1.5	200 @ 300 @ 25	USD
USD142H	3	Si	400	400	1000 @ 1.0	5.0 @ 25	1.5	200 @ 400 @ 25	USD
USD142J	3	Si	500	500	1000 @ 1.0	5.0 @ 25	1.5	200 @ 500 @ 25	USD
USD162B	2	Si	100	100	5000 @ 1.2	10 @ 25	1.5	200 @ 100 @ 25	USD
USD162D	3	Si	200	200	5000 @ 1.2	10 @ 25	1.5	200 @ 200 @ 25	USD
USD162F	3	Si	300	300	5000 @ 1.2	10 @ 25	1.5	200 @ 300 @ 25	USD
USD162H	3	Si	400	400	5000 @ 1.2	10 @ 25	1.5	200 @ 400 @ 25	USD
USD162J	3	Si	500	500	5000 @ 1.2	10 @ 25	1.5	200 @ 500 @ 25	USD
USD5051B	2	Si	100	100	5000 @ 1.2	10 @ 25	1.5	5000 @ 100 @ 25	USD
USD5051D	2	Si	200	200	5000 @ 1.2	10 @ 25	1.5	5000 @ 200 @ 25	USD
USD5051F	2	Si	300	300	5000 @ 1.2	10 @ 25	1.5	5000 @ 300 @ 25	USD
USD5051H	2	Si	400	400	5000 @ 1.2	10 @ 25	1.5	5000 @ 400 @ 25	USD
USD5051J	2	Si	500	500	5000 @ 1.2	10 @ 25	1.5	5000 @ 500 @ 25	USD
USD5091B	2	Si	100	100	1000 @ 1.0	5.0 @ 25	1.5	5000 @ 100 @ 25	USD
USD5091D	2	Si	200	200	1000 @ 1.0	5.0 @ 25	1.5	5000 @ 200 @ 25	USD
USD5091F	2	Si	300	300	1000 @ 1.0	5.0 @ 25	1.5	5000 @ 300 @ 25	USD
USD5091H	2	Si	400	400	1000 @ 1.0	5.0 @ 25	1.5	5000 @ 400 @ 25	USD
USD5091J	2	Si	500	500	1000 @ 1.0	5.0 @ 25	1.5	5000 @ 500 @ 25	USD

NOTATIONS

Under Use

1. General Purpose
2. Power Rectifier
3. Magnetic Amplifier

Other

4. For half wave resistive load average over 1 cycle

Under Reverse Current

5. Dynamic

Under Mfr.

6. Available in stack form from that manufacturer

Following any temperature reading these symbols apply

A — Ambient
C — Case
J — Junction
S — Storage
* — Forced Convection — 2000LFM

Manufacturers should be contacted for value and test condition for surge current and maximum peak recurrent current.

CHARACTERISTICS CHART of SILICON ZENER or AVALANCHE DIODES

TYPE NO.	Zener or Avalanche Voltage Range MIN. Eb1 (volts)	MAX. Eb2 (volts)	@ Iz (ma)	Dynamic Impedance Z @ Iz (ohms)	(ma)	MAX. DISS. (mw)	TEMP. CO-EF-FICIENT %/°C	MFR. {See code at start of chart}
1N664	7.38	9.02	10	10	10	250		WEC
1N665	10.8	13.2	20	15	20	250		WEC
1N666	13.5	16.5	15	20	15	250		WEC
1N667	16.2	19.8	12	25	12	250		WEC
1N668	19.8	24.2	10	30	10	250		WEC
1N669	24.3	29.7	9	35	9	250		WEC
1N670	61.2	74.8	3	130	3	250		WEC
1N671	90	110	2	300	2	250		WEC
1N672	135	165	1.5	800	1.5	250		WEC
1N1416	7.38	9.02	10	8.0	10	10W		WEC
1N1417	10.8	13.2	10	18	10	10W		WEC
1N1418	13.5	16.5	10	20	10	10W		WEC
1N1419	16.2	19.8	10	22	10	10W		WEC
1N1420	19.8	24.2	10	25	10	10W		WEC
1N1421	24.3	29.7	10	23	10	10W		WEC
1N1422	61.2	74.8	10	40	10	10W		WEC
1N1423	90	110	10	60	10	10W		WEC
1N1424	135	165	10	70	10	10W		WEC
1N1425	7.38	9.02	10	10	10	1000		WEC
1N1426	10.8	13.2	20	15	20	1000		WEC
1N1427	13.5	16.5	15	20	15	1000		WEC
1N1428	16.2	19.8	12	25	12	1000		WEC
1N1429	19.8	24.2	10	30	10	1000		WEC
1N1430	24.3	29.7	9	35	9	1000		WEC
1N1431	61.2	74.8	3	135	3	1000		WEC
1N1432	90	110	2	300	2	1000		WEC
1N1433	135	165	1.5	800	1.5	1000		WEC
1N1507	3.6	4.3	35	1.25	35	750	.04	INRC
1N1508	4.3	5.1	30	1.25	30	750	0	INRC
1N1509	5.1	6.2	26	2	26	750	.03	INRC
1N1510	6.2	7.5	22	2.5	22	750	.05	INRC
1N1511	7.5	9.1	18	4	18	750	.06	INRC
1N1512	9.1	11	15	6	15	750	.07	INRC
1N1513	11	13	12	10	12	750	.075	INRC
1N1514	13	16	10	20	10	750	.08	INRC
1N1515	16	20	8	40	8	750	.085	INRC
1N1516	20	24	6	60	6	750	.09	INRC
1N1517	24	30	6	75	5	750	.095	INRC
1N1518	3.9	4.3	50	1	50	1000	.04	INRC
1N1519	4.3	5.1	40	1	40	1000	0	INRC
1N1520	5.1	6.2	35	1.5	35	1000	.03	INRC
1N1521	6.2	7.5	30	2	30	1000	.05	INRC
1N1522	7.5	9.1	25	3	25	1000	.06	INRC
1N1523	9.1	11	20	4.5	20	1000	.07	INRC
1N1524	11	13	15	7.5	15	1000	.075	INRC
1N1525	13	16	13	15	13	1000	.08	INRC
1N1526	16	20	10	30	10	1000	.085	INRC
1N1527	20	24	9	45	9	1000	.09	INRC
1N1528	24	30	7	60	7	1000	.095	INRC
1N1530	8.0	8.8	10	15	10		.014	HSD
1N1530A	8.0	8.8	10	15	10		.007	HSD
1N1588	3.6	4.3	150	.5	150	3500	.04	INRC
1N1589	4.3	5.1	125	.5	125	3500	0	INRC
1N1590	5.1	6.2	110	.75	110	3500	.03	INRC
1N1591	6.2	7.5	100	1	100	3500	.05	INRC
1N1592	7.5	9.1	80	1.5	80	3500	.06	INRC
1N1593	9.1	11	70	2.5	70	3500	.07	INRC
1N1594	11	13	50	4	50	3500	.075	INRC
1N1595	13	16	40	7.5	40	3500	.08	INRC
1N1596	16	20	35	15	35	3500	.085	INRC
1N1597	20	24	30	22.5	30	3500	.09	INRC
1N1598	24	30	25	30	25	3500	.095	INRC
1N1599	3.6	4.3	500	.25	500	10W	.04	INRC
1N1600	4.3	5.1	400	.25	400	10W	0	INRC
1N1601	5.1	6.2	350	.4	350	10W	.03	INRC
1N1602	6.2	7.5	300	.5	300	10W	.05	INRC
1N1603	7.5	9.1	250	.75	250	10W	.06	INRC
1N1604	9.1	11	200	1.25	200	10W	.07	INRC
1N1605	11	13	170	2	170	10W	.075	INRC
1N1606	13	16	140	4	140	10W	.08	INRC
1N1607	16	20	110	7.5	110	10W	.085	INRC
1N1608	20	24	90	12	90	10W	.09	INRC
1N1609	24	30	70	15	70	10W	.095	INRC
3R3.9	3.6	4.3	850	20	120	3000	.04	AUT
3R4.7	4.3	5.1	700	10	120	3000	.00	AUT
3R5.6	5.1	6.2	625	4.5	120	3000	.03	AUT
3R6.8	6.2	7.5	525	6.5	60	3000	.05	AUT
3R8.2	7.5	9.1	425	9	60	3000	.06	AUT
3R10	9.1	11.0	350	12	60	3000	.07	AUT
3R12	11	13	275	25	30	3000	.075	AUT
3R15	13	16	225	50	30	3000	.08	AUT
3R18	16	20	200	70	30	3000	.085	AUT
3R22	20	24	160	120	30	3000	.09	AUT
3R27	24	30	125	200	30	3000	.095	AUT

CHARACTERISTICS CHART of SILICON ZENER or AVALANCHE DIODES

TYPE NO.	Zener or Avalanche Voltage Range MIN. E_{b1} (volts)	MAX. E_{b2} (volts)	@ I_z (ma)	Dynamic Impedance Z (ohms)	@ I_z (ma)	MAX. DISS. (mw)	TEMP. CO-EF-FICIENT %/°C	MFR. (See code at start of chart)
GZ1	2.0	3.2	5.0	45	10	250		HSD
GZ2	3.0	3.9	5.0	40	10	250		HSD
GZ3	3.7	4.5	5.0	30	10	250		HSD
GZ4	4.3	5.4	5.0	25	10	250		HSD
GZ5	5.2	6.4	5.0	10	10	250		HSD
GZ6	6.2	8.0	5.0	5.0	10	250		HSD
PZ8.2	7.5	9.1	50	2.0	50		.04	USS
PZ10	9.1	11	50	2.3	50		.058	USS
PZ12	11	13	50	2.5	50		.059	USS
PZ15	13	16	50	3.0	50		.060	USS
PZ18	16	20	50	5.0	50		.062	USS
PZ22	20	24	15	7.0	15		.064	USS
PZ27	24	30	15	10	15		.066	USS
PZ33	30	36	15	15	15		.068	USS
PZ39	36	43	15	26	15		.07	USS
PZ47	43	51	15	32	15		.072	USS
PZ56	51	62	15	40	15		.075	USS
PZ68	62	75	7.5	50	7.5		.08	USS
PZ82	75	91	7.5	85	7.5		.086	USS
PZ100	91	110	7.5	220	7.5		.093	USS
PZ120	110	130	7.5	350	7.5		.10	USS
PZ150	130	160	7.5	450	7.5		.12	USS
indicates stud mounting, for Axial lead use Prefix LPZ								
R3.9	3.6	4.3	250	20	40	1000	.04	AUT
R4.7	4.3	5.1	200	10	40	1000	.00	AUT
R5.6	5.1	6.2	175	4.5	40	1000	.03	AUT
R6.8	6.2	7.5	150	6.5	20	1000	.05	AUT
R8.2	7.5	9.1	120	9	20	1000	.06	AUT
R10	9.1	11.0	100	12	20	1000	.07	AUT
R12	11	13	80	25	10	1000	.075	AUT
R15	12	16	65	50	10	1000	.08	AUT
R18	16	20	55	70	10	1000	.085	AUT
R22	20	24	45	120	10	1000	.09	AUT
R27	24	30	35	200	10	1000	.095	AUT
SV3170	5.9	6.5	7.5	20	7.5	200	.02	TRA
SV3171	6.7	7.4	10	10	10	200	.01	TRA
SV3173	8.0	8.8	10	15	10	200	.005	TRA
SV3174	8.0	8.8	10	15	10	200	.003	TRA
SV3175	8.0	8.8	10	15	10	200	.002	TRA
SV3176	8.0	8.8	10	15	10	200	.001	TRA
SV3206	16	17.6	10	30	10	400	.002	TRA
SV3027	16	17.6	10	30	10	400	.001	TRA
SX56	5.1	6.1	5.0	40	5.0	300	.02	GECB
SX68	6.1	7.5	5.0	20	5.0	300	.04	GECB
Z2A36	3.40	3.80	20	35	20	1000	.057	STCB
Z2A39	3.70	4.15	20	33	20	1000	.05	STCB
Z2A43	4.05	4.55	20	31	20	1000	.046	STCB
Z2A51	4.85	5.40	20	26	20	1000	.01	STCB
Z2A56	5.30	5.95	20	23	20	1000	.012	STCB
Z2A62	5.85	6.55	20	19	20	1000	.03	STCB
Z2A75	7.10	7.90	20	15	20	1000	.05	STCB
Z2A82	7.80	8.70	20	19	20	1000	.054	STCB
Z2A91	8.60	9.60	20	23	20	1000	.06	STCB
Z2A110	10.4	11.5	20	32	20	1000	.068	STCB
Z2A120	11.4	12.5	20	36	20	1000	.072	STCB
Z2A130	12.4	14.0	20	43	20	1000	.076	STCB

CHARACTERISTICS CHART of MISCELLANEOUS DIODE TYPES

TYPE NO.	CLASSIFI-CATION	DESCRIPTION	MFR.
1N25A	1	L-Band Mixer, L_c — 6.5 db. max.	SYL
1N26A	1	K-Band Mixer, L_c— 7.5 db. max.	SYL
1N53B	1	K_a Band Mixer, L_c— 6.5 db.	SYL
1N78A	1	K_u Band Mixer, L_c— 7.0 db. max.	SYL
1N358A	1	1-12.4 Kmc. video detector, Figure of merit = 30	SYL
1N1610	1	3-12.4 Kmc. video detector, Figure of merit — 15	SYL
1N1611	1	X Band video detector, Figure of merit — 130 min.	SYL

CHARACTERISTICS CHART of SWITCHING DIODES

TYPE NO.	MAT	PIV (volts)	MAX. CONT. REV. WORK. VOLT. (volts)	Min. Forward Current @ 25°C: I_f @ E_f (mA) (volts)	Reverse Impedance @ 25°C: Z (K ohms)	Reverse Impedance @ 25°C: VOLTAGE RANGE E_{b1} to E_{b2} (volts)	Recovery Characteristics: TEST CONDITIONS Fwd. Rev. I_f to E_b (ma) (volts)	Recovery Characteristics: $Z_{rec.}$ @ time (t) (K ohms) (usec)	MFR. (See code at start of charts)
1N696	Si		40 min. @ 10ua	10 @ 1.0			t_{rt} =.005 (90% pt If = I_r = 20 ma)		WEC
1N697	Si		120 min. @ 10ua	250 @ 1.0			t_{rt} =.03 (90% pt If = I_r = 100ma)		WEC
1N698	Ge	25	15	30 @ .52	1000	1.5 to 20	5 to 5	20 @ .50 200 @ 3.5	AMP
1N699	Ge	105 @ 70°C.	80	100 @ 1.0	300	75 @ 70°C.	5 to 40	50 @ .30	CBS
G2	Ge	70	60	5.0 @ 1.0	400	20 to 50	30 to 35	200 @ .20	GAH
G17	Ge	70	60	15 @ 1.0	500	10 to 60	5 to 40	400 @ .20	GAH
G18	Ge	70	60	7.5 @ 1.0	500	10 to 60	5 to 40	400 @ .20	GAH
G107	Ge	90	60	10 @ 1.0	1000	50	5 to 40	400 @ .10	GAH
G108	Ge	75	60	10 @ 1.0	500	50	5 to 40	200 @ .10	GAH
G127	Ge	70	60	30 @ 1.0	500	10 to 50	5 to 40	200 @ .10	GAH
GTD990	Ge	70	60	100 @ 1.0	400	10 to 50	30 to 40	50 @ .50 400 @ 3.5	GTC
HD6648	Si	100		6.0 @ 1.5	2500	75	30 to 35	400 @ 1.0	HUG
HD6649	Si	200		6.0 @ 1.5	5800	175	30 to 35	400 @ 1.0	HUG
HD6651	Si	100		15 @ 1.5	2500	75	30 to 35	400 @ 1.0	HUG
HD6652	Si	200		15 @ 1.5	5800	175	30 to 35	400 @ 1.0	HUG
OA182	Ge	100		100 @ .80					TFKG
OA186	Ge	90		5.0 @ 1.0	400	20 to 50	30 to 35	400 @ 3.5	TFKG
Q5-100	Ge			10 @ .38	50	5.0	1.6 to 3.0	7.5 @ .003	QSC
Q5-250	Ge			10 @ .38	50	5.0	1.6 to 3.0	7.5 @ .005	QSC
Q6-100	Ge			10 @ .38	60	6.0	1.6 to 3.0	7.5 @ .003	QSC
Q6-250	Ge			10 @ .38	60	6.0	1.6 to 3.0	7.5 @ .005	QSC
Q10-200	Ge			10 @ .39	100	10	1.6 to 3.0	7.5 @ .005	QSC
Q10-300	Ge			10 @ .39	100	10	1.6 to 3.0	7.5 @ .006	QSC
Q10-350	Ge			5.0 @ 1.0	100	10	100 to 5.0	10 @ 4.0	QSC
Q10-400	Ge			10 @ .39	100	10	1.6 to 3.0	7.5 @ .007	QSC
Q10-500	Ge			10 @ .39	100	10	1.6 to 3.0	7.5 @ .008	QSC
Q10-600	Ge			10 @ .39	100	10	1.6 to 3.0	7.5 @ .009	QSC
Q10-750	Ge			10 @ .39	100	10	1.6 to 3.0	7.5 @ .012	QSC
Q20-650	Ge			10 @ .45	200	20	1.6 to 3.0	7.5 @ .010	QSC
Q30-750	Ge			10 @ .54	300	30	1.6 to 3.0	7.5 @ .012	QSC
S131	Si	40	36	400 @ 1.0	120M	30	5 to 30	100 @ .50	SSD
S132	Si	80	70	400 @ 1.0	240M	60	5 to 40	100 @ .50	SSD
S133	Si	150	130	400 @ 1.0	480M	120	5 to 40	100 @ .50	SSD
S134	Si	200	180	400 @ 1.0	640M	160	5 to 40	100 @ .50	SSD

THE FOLLOWING MANUFACTURERS HAVE ANNOUNCED THAT THEY HAVE BEGUN SUPPLYING THE INDICATED PREVIOUSLY REGISTERED DIODES AND RECTIFIERS

BENDIX: 1N536, 1N537, 1N538, 1N540, 1N547
BOGUE: 1N253, 1N254, 1N255, 1N256, 1N440, 1N440B, 1N441, 1N441B, 1N442, 1N442B, 1N443, 1N443B, 1N444, 1N444B, 1N445, 1N445B
BRADLEY: 1N253, 1N254, 1N255, 1N256, 1N316, 1N317, 1N318, 1N319, 1N320, 1N323, 1N324, 1N325, 1N326, 1N327, 1N332, 1N333, 1N334, 1N335, 1N336, 1N337, 1N338, 1N340, 1N341, 1N342, 1N343, 1N344, 1N345, 1N346, 1N347, 1N348, 1N349, 1N359, 1N360, 1N361, 1N362, 1N363, 1N440, 1N441, 1N442, 1N443, 1N444, 1N445, 1N519, 1N520, 1N521, 1N522, 1N423, 1N530, 1N531, 1N532, 1N533, 1N534, 1N535, 1N536, 1N537, 1N538, 1N539, 1N540, 1N547, 1N550, 1N551, 1N552, 1N553, 1N554, 1N555, 1N559, 1N599A, 1N600, 1N600A, 1N601, 1N601A, 1N602, 1N602A, 1N603, 1N603A, 1N604, 1N604A, 1N605, 1N605A, 1N606, 1N606A, 1N607A, 1N608A, 1N609A, 1N610A, 1N611A, 1N612A, 1N1058, 1N1059, 1N1060, 1N1061, 1N1062, 1N1063, 1N1095, 1N1096, 1N1100, 1N1101, 1N1102, 1N1103, 1N1104, 1N1105, 1N1115, 1N1116, 1N1117, 1N1118, 1N1341, 1N1342, 1N1343, 1N1344, 1N1345, 1N1346, 1N1347, 1N1348
CBS-HYTRON: 1N34, 1N68A, 1N81, 1N111, 1N112, 1N113, 1N114, 1N115, 1N191, 1N192
CLEVITE: 1N457, 1N458, 1N459, 1N482A, 1N484, 1N486, 1N488, 1N629
GAHAGAN: 1N295
HUGHES: 1N482, 1N482A, 1N482B, 1N483, 1N483A, 1N483B, 1N484, 1N484A, 1N484B, 1N485, 1N485A, 1N485B, 1N486, 1N486A, 1N487, 1N487A, 1N448, 1N488A
INTERNATIONAL RECTIFIER: 1N430, 1N430A, 1N430B, 1N547, 1N1095, 1N1096
KEMTRON: 1N21WE, 1N23WE, 1N78A, 1N149, 1N150, 1N160
PACIFIC SEMICONDUCTORS: 1N588, 1N589, 1N645, 1N646, 1N647, 1N648, 1N649, 1N1134, 1N1135, 1N1136, 1N1137, 1N1138, 1N1139, 1N1140, 1N1141, 1N1142, 1N1143, 1N1143A, 1N1144, 1N1145, 1N1146, 1N1147, 1N1148, 1N1149
RADIO RECEPTOR: 1N126A, 1N127A, 1N191, 1N192, 1N270, 1N276
RAYTHEON: 1N55B, 1N67A, 1N68A, 1N95, 1N126, 1N127, 1N128, 1N191, 1N198, 1N536, 1N547, 1N645, 1N646, 1N647, 1N648, 1N1095
SYLVANIA: 1N415B, 1N415C, 1N415D, 1N415E, 1N416B, 1N416C, 1N416D, 1N416E
TRANSITRON: 1N429

SEMICONDUCTOR & SOLID-STATE BIBLIOGRAPHY

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Field-Effect Varistor	Bell Labs Record April 1958	Constant-current feature of this two-terminal passive semiconductor makes it suitable for current regulation.	
Proposed High-Frequency gative-Resistance Diode	Bell System Technical Journal March 1958	Description and analysis of a proposed semiconductor diode designed to operate as an oscillator when mounted in a suitable microwave cavity.	W. T. Read, Jr.
Transistorized Repeater for e With the 45BN Cable Carr System	Communications and Electronics (AIEE) March 1958	A new repeater has been developed for cable carrier use. Transistors have been used extensively to reduce the size and power requirements.	V. Babin R. Fish
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rcraft Speaker System Uses ansistorized Modules	Electrical Design News March 1958	Transistorized modules distribute the sound in a passenger aircraft public address system.	
ybrid Loop Generates Square oot Functions	Electrical Design News March 1958	A solid state voltage to digital converter uses a hybrid loop to accomplish repeatable high speed generation of square root functions.	
ven Control, Transistor abilize Oscillator	Electrical Design News March 1958	A stable oven and a highly compensated transistorized circuit are features of a new 100 *kc* crystal oscillator.	
lenium Rectifier Selection nd Circuit Design	Electrical Manufacturing April 1958	Single-phase, half-wave and bridge circuit with common load components are analyzed with current and voltage behavior shown graphically.	R. C. Hitchcock
pplying the Hall Effect to ractical Magnet Testing	Electrical Manufacturing April 1958	Indium-arsenide probes that generate Hall voltages in magnetic fields promise simplified precision magnetic measurements.	G. R. Hennig
licon Diode Application Notes	Electronic Design March 5, 1958	Equations and criteria for designing silicon diodes in practical circuits.	Arnold Bergson
ransistor Voltage Standards	Electronic Design March 5, 1958	Proposal for standardization of power supply voltages for transistor circuits. Method used to select these voltage standards.	W. W. Wells
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ener Diode Characteristics	Electronic Design March 19, 1958	Chart of Zener diodes listed by their electrical characteristics in order of minimum and maximum Zener voltage.	
he Thyristor	Electronic Design March 19, 1958	Construction, characteristic curves and circuit applications of the Thyristor.	L. E. Barton
he Resisting Transistor or Servo Design	Electronic Design April 2, 1958	New technique effectively uses the transistor as a variable resistor between the power supply and the load.	T. R. Nisbet
D.C. Feedback Equations or Transistor Amplifiers	Electronic Design April 16, 1958	Three configurations are considered, collector voltage feedback, collector current feedback, and combination feedback.	Howard Lefkowitz
Transistorized Static nverter Design	Electronic Design April 16, 1958	Background fundamental, design details, cooling, transients, performance data and improvements discussed.	J. F. Lohr
Determining Frequency of Unijunction-Transistor Relaxation Oscillators	Electronic Equipment Engineering March 1958	A monograph is provided in which for a given value of R_1 and C_1 the frequency determining elements, two basic oscillation-frequency characteristics may be obtained	T. P. Sylvan
Silver-Zinc Batteries for Missile Applications	Electronic Equipment Engineering April 1958	Battery composition, primary and secondary batteries, discharge factors, temperature effects, and battery storage are some of the topics discussed.	G. F. Hartman
Transistors and Diodes in Strong Magnetic Fields	Electronic Industries March 1958	Discussion of parameter change and orientation sensitivity of transistors and diodes in strong magnetic fields.	H. A. Kampf
Medium Power Silicon Rectifiers	Electronic Industries March 1958	A new design consisting of a PIN diode structure has been developed. Preparation, forming, and electrical characteristics are discussed.	R. J. Andres E. L. Steele
Temperature Measurements with Thermistors	Electronic & Radio Engineer (British) March 1958	Devices described are an industrial thermometer (0-100°C), a medical thermometer (85-105°F), and a high-sensitivity unit using a two-stage transistor amplifier.	C. J. Anderson

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TITLE	PUBLICATION	CONDENSED SUMMARY	AUTHORS
Fast Transistor Relay	Electronics March 14, 1958	Push-pull switching unit capable of handling up to 10 amperes has a rise time of 50 μsec.	D. L. Anderson
Amplifier Design Curves	Electronics March 14, 1958	Charts aid determination of transistor or tube types, numbers of stages, and number of specifications of transformers for double-tuned *h-f* amplifiers.	A. E. Hayes, J
Magnetic Inverter Uses Tubes or Transistors	Electronics March 14, 1958	Collector and emitter coil windings of transistor or plate and grid windings of tube are oppositely connected to multivibrator.	C. H. R. Campb
Rapid Conversion of Hybrid Parameters	Electronics March 28, 1958	Chart and nomograph simplify conversion of grounded-base transistor parameters to grounded-emitter and grounded-collector forms.	S. Sherr
Solid-State Thyratron Switches Kilowatts	Electronics March 28, 1958	Circuits discussed are static switches, synchronized inverters, *d-c* to *d-c* converters, regulated *d-c* power supplies, dynamic braking, surge voltage suppression and power flip-flop.	R. P. Frenzel F. W. Gutzwill
Designing Transistor A-F Power Amplifiers	Electronics April 11, 1958	Amplifiers deliver 45W to a 4-ohm load. Neither series nor quasicomplementary types use a driver or output transformer.	M. B. Herscher
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On the Statistical Mechanics of Impurity Conduction in Semiconductors	IBM Journal of Research and Development April 1958	The statistical mechanics of the impurity electron states for a semiconductor with a low density of donors, and a small amount of acceptor compensation is analyzed.	P. H. Price
Some Notes on the Hybrid-Pi Transistor Equivalent Circuit	IRE Transactions on Broadcast and TV Receivers March 1958	The transistor amplifier and equivalent circuit; the constant current generator; the forward-biased junction; the diffusion capacitance; frequency independence of emitter current are some of the topics discussed.	C. R. Wilhelmse
A Transistor Univibrator with Stabilized Pulse Duration	IRE Transactions on Circuit Theory March 1958	Use is made of a simple model of the basic emitter-coupled univibrator, or monostable multivibrator for a facile understanding of circuit operation.	D. J. Hamilton
Photoelectric Cells—A Review of Progress	IRE Transactions on Component Parts March 1958	A tutorial review of the various devices that exhibit a photoelectric effect. An exposition of the underlying physical principles.	J. D. McGee
Thermistors for the Gradual Application of Heater Voltage to Thermionic Tubes	IRE Transactions on Electronic Computers March 1958	Thermistors which have large negative temperature coefficients of resistance can be aptly used for the gradual application of heater voltage to thermionic tubes.	J. J. Gano G. F. Sandy
A Transistorized Four-Quadrant Time-Division Multiplier with an Accuracy of 0.1%	IRE Transactions on Electronic Computers March 1958	Description of a circuit independent of the transistor characteristics, and which requires no complicated balancing adjustments.	H. Schmid
Transistor Characteristics for Direct-Coupled Transistor Logic Circuits	IRE Transactions on Electronic Computers March 1958	Methods for the specification of acceptance requirements for *dctl* transistors and the relation of these specifications to logic design rules are discussed.	J. W. Easley
Direct Coupled Transistor Logic Circuitry	IRE Transactions on Electronic Computers March 1958	Logical design rules are given for use with transistors. The implications of the use of silicon transistors are discussed.	J. R. Harris
The Use of Transistors in Physiological Amplifiers	IRE Transactions on Medical Electronics March 1958	A physiological amplifier having a voltage gain of 10,000 was designed using low level *d-c* differential amplifiers with hearing aid transistors.	T. Bickart E. F. Macnichol
Measurement of Bioelectric Potentials With Microelectrodes and Neutralized Input Capacity Amplifiers	IRE Transactions on Medical Electronics March 1958	Vacuum tube and transistorized versions of neutralized amplifiers are briefly described.	E. Amatniek
Some Properties of Gallium Arsenide-Germanium Mixtures (Letter to the Editor)	Journal of Applied Physics March 1958	Results indicate that the solubility of germanium in gallium arsenide is probably less than two atomic percent.	D. A. Jenny R. Braunstein
Radiation Induced Noise in P-N Junctions	Journal of Applied Physics March 1958	Noise is induced in a *p-n* junction when it is bombarded by high-energy radiation. Mean square noise current predictions are verified.	W. H. Fonger J. J. Loferski P. Rappaport
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ost-Bombardment Conductiv- ity in MgO Crystals	Physical Review March 15, 1958	Electrical conductivity following the termination of bombardment by 1.3-Mev electrons has been observed in MgO crystals.	R. A. Shatas J. F. Marshall M. A. Pomerantz
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The Effects of Short Duration Neutron Radiation on Semiconductor Devices.	Proceedings of the I.R.E. March 1958	Effects on principle parameters of semiconductor devices on exposure to short-duration, high-intensity neutron radiation from a U-235 critical assembly.	W. V. Behrens J. M. Shaull
Theory of Junction Diode and Junction Transistor Noise	Proceedings of the I.R.E. March 1958	Shot noise formulas for devices in which all current is carried by one type of carrier, the carrier flow is one-dimensional, and the recombination is by volume recombination.	A. van der Ziel A. G. T. Becking
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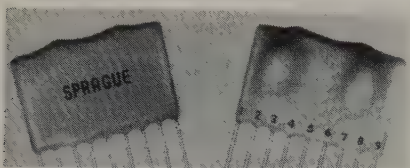
Variation of Junction Transistor Current Amplification Factor with Emitter Current (Correspondence)	Proceedings of the I.R.E. March 1958	On the analyses given by Webster and Rittner which take into account the influence of the electric field as well as diffusion.	A. W. Matz
An Extended General Network Theorem on Rectification (Correspondence)	Proceedings of the I.R.E. March 1958	Discussion of Gewartowski's Theorem about the need for nonlinear resistance for rectified *a-c* output.	H. Stockman
Measuring Noise Figures of Transistor Amplifiers (Correspondence)	Proceedings of the I.R.E. March 1958	Modifications of equations for unmatched conditions of the output impedance of the noise diode and the input impedance of the amplifier under test.	A. Y. Anouchi
Large-Area Germanium Power Transistors	RCA Review March 1958	Both *p-n-p and n-p-n* experimental alloy junction power transistors have been developed to operate at collector currents of 10 amperes or more.	B. N. Slade J. Printon
A Hysteresis Effect in Cadmium Selenide and its use in a Solid-State Image Storage Device	RCA Review March 1958	A brief description is given of a new hysteresis effect in cadmium selenide photoconductive powder.	F. H. Nicoll
Differential Method of Lag Compensation in Photoconductive Devices	RCA Review March 1958	Method for reducing the effective response time of a photoconductive device regardless of the source of lag.	H. Borkan P. K. Weimer

New Products

Multiple Logic Package

Sprague's new type 200C9 Multiple Logic Package is a single ceramic-base printed circuit with integral resistors and capacitors. It can be used as a flip-flop, pulse generator,

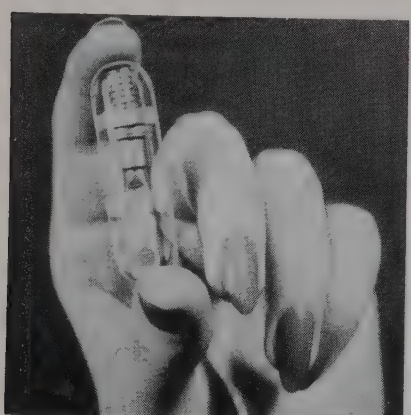


or gating, amplifying, clipping, shaping, or delaying circuits by simple external connections to the 9 leads, which have been brought out from the printed circuit network. Only 1" high by 1½" long by ½" thick, the new Sprague assembly for low-speed transistor circuits contains 10 resistors, 5 capacitors, and 2 transistors in one single encapsulation. Thus the number of parts to be inspected, handled, and soldered in a finished equipment has been drastically reduced with accompanying cost savings.

Circle 139 on Reader Service Card

Miniature Silicon Power Rectifier

A new type of diffused junction silicon power rectifier has been developed in the research laboratories of Fansteel Metallurgical Corporation. This small unit is rated for continuous service at 20 amperes *dc*

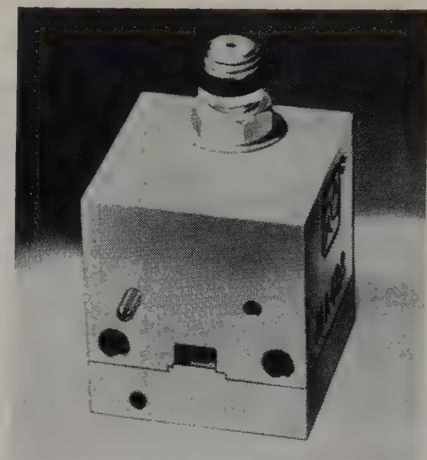


at maximum peak reverse potentials up to 400 volts. Four of these rectifiers in a full wave bridge circuit will provide power for a 10 horsepower 230-volt *dc* motor.

Circle 164 on Reader Service Card

Broad Band Microwave Diode

A new broadband high sensitivity microwave silicon diode, Type MA-428, has been developed by Microwave Associates. The diode exhibits high tangential sensitivity over the entire 50 to 75 *kmc* frequency range. The manufacturer estimates system noise figures between 15 to 18 *db* can be achieved using a matched pair of these diodes as mixers in a rat race power divider (MA-606) bal-



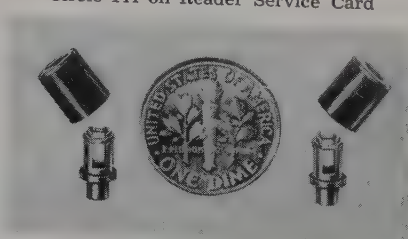
anced mixer assembly in conjunction with a low noise *if* strip. The MA-428 may be used also as a high sensitivity detector in low level video receiver applications.

Circle 128 on Reader Service Card

Test Jack

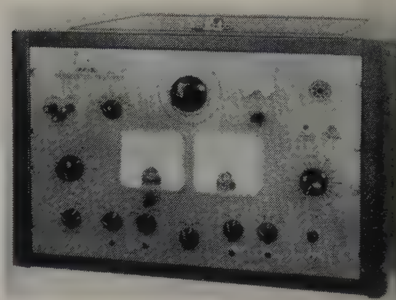
Etched and printed circuit engineers can solve test point and monitoring problems by use of a tiny test jack developed by Grayhill, Inc., which is designed for use on printed circuit boards. It accommodates standard phone tip plugs of .081" to .0825" diameter. Only ¼" o.d. and approximately ¼" high, it rivets to the board like an eyelet.

Circle 144 on Reader Service Card



Transistor Test Set

A new general purpose transis test set has been announced by Bai Atomic, Inc. The B-A Model K is a versatile precision instrument analyzing transistors at frequen from 100 *cps* to 200 *kc*, for both l oratory and production work. It t fers a current range of from 100 to 1 amp. with two regulated sen conductor power supplies for b

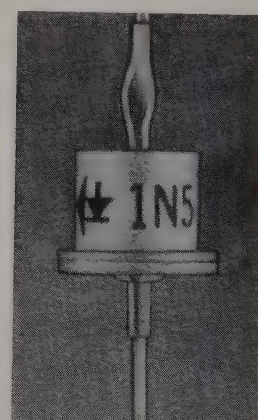


voltages and currents. Special mo els available for use up to 2 am The direct measurements obtain are based on "h" parameters.

Circle 140 on Reader Service Card

JAN Type Silicon Rectifiers

Start of mass production of thr new JAN types of silicon power re tifier, designed for critical militar applications, is announced by Gen eral Instrument Corporation. Thes units cover the range from 200 600 volts peak inverse, and from 75 *ma dc* output at 50° C to 250 *ma* output at 150° C. They meet all mil tary requirements for shock, vibra

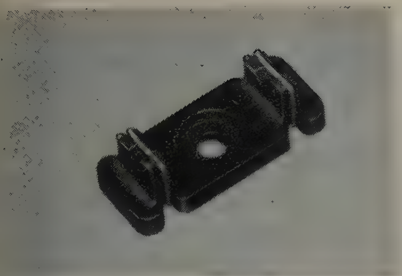


tion, acceleration, centrifuging temperature cycling and humidity can be operated successfully at temperatures ranging from —55° C. to +165° C. and can be stored at temperatures ranging from —65° to +180° C.

Circle 153 on Reader Service Card

Germanium Diode Holder

Grayhill, Inc., manufacturers of an extensive line of miniature components, offer a germanium diode



older (Model 17-1). It features gold plated spring tension clips which grip the diode with a tight snap fit. The overall dimensions are $1\frac{5}{16}''$ long x $\frac{5}{8}''$ wide. Center to center of clips .635". Loops in spring clips may be used as terminals.

Circle 147 on Reader Service Card

Tubeless Power Supply

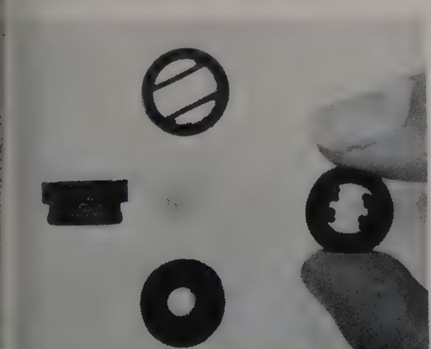
A tubeless type power supply for rack mounting is now available from Nutron Manufacturing Co. Nutron's power supply features good regulation, low ripple, wide voltage range coupled with high current capacity, low output impedance, and stability. The new model RM-1A is especially

useful for testing and developing transistor devices, for basic research in physics, magnetics, chemistry, medicine, etc. Designed for both laboratory and industrial use, it has wide application wherever a smooth variable source of regulated *d-c* or *a-c* is required.

Circle 169 on Reader Service Card

Transistor Mounting

The Delbert Blinn Company announces a new transistor mounting that provides a standardized mounting of all transistors regardless of size or shape. It offers shock resistance and prevents movement of the transistor even when subjected to severe vibration. Good heat sinking is afforded due to long transistor

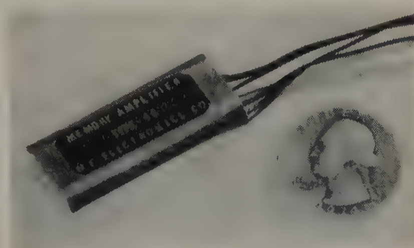


leads; and the quality of low moisture absorption, that is virtually unaffected by changes in either fresh or salt water, is another feature of this transistor mounting.

Circle 172 on Reader Service Card

Indicating Flip-Flop

M. F. Electronics announces the Type 20, an indicating Flip-Flop in a sealed unit. It is designed to operate as a combined binary counter and indicator at speeds up to 20 *kc*.

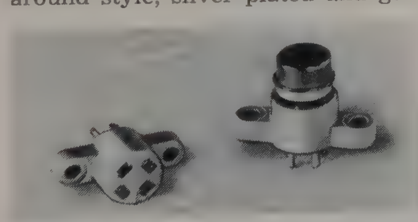


No additional transistors are needed to drive neon indicators and only one low supply voltage is required. Each unit is capable of driving a succeeding unit, allowing as long a binary chain as required. The only inter-unit components required are one coupling capacitor per stage.

Circle 175 on Reader Service Card

Transistor Socket

This new socket was designed by Grayhill, in conjunction with a leading transistor manufacturer, for use with the new 3 and 4 Pin JETEC 30 Transistors. The socket body is molded from mica-filled phenolic per MIL-M-14, Type MFE. The beryllium copper contacts are wraparound style, silver plated and gold

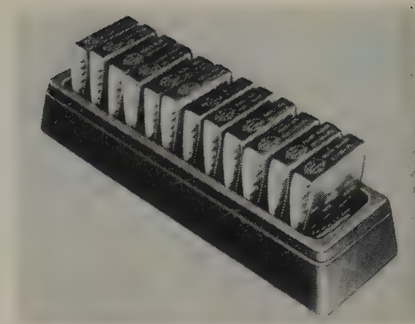


flashed for good contact and corrosion resistance.

Circle 143 on Reader Service Card

Thermistors

Twelve representative thermistors, with complete curves and specifications for each, are included in a new Experimenter's Thermistor Kit being offered by Fenwal Electronics, Inc. The kit, Model G200, has been designed to assist engineers in familiarizing themselves with thermistors, and for experimental work. The kit contains two glass thermistor probes, three beads, two discs, three rods, and two washers. Each thermistor is

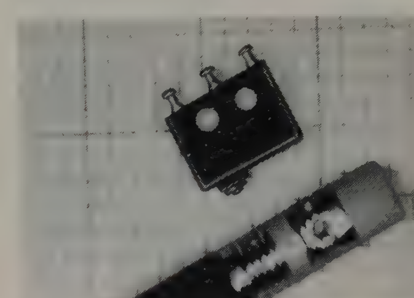


separately packaged in its own "matchbook" cover and complete performance data is imprinted on the cover.

Circle 127 on Reader Service Card

Miniature Switch

A precision snap-action switch has been announced by Micro Switch. Designated the Type "SX" Sub-subminiature, this switch provides opportunities for the designer of compact devices where space and weight savings are important. The "SX" measures only .5 x .35 x .2 inch (on the case) and weighs but 1/28th

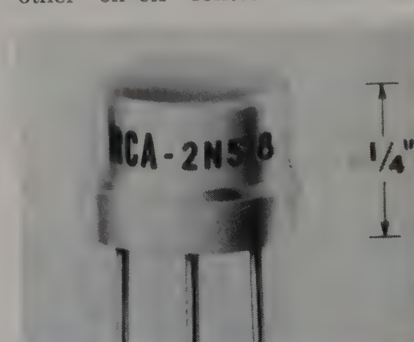


ounce. The case, cover and plunger of the "SX" are made of high-strength plastic. Contacts are of fine silver. The unique snap-action spring is fabricated from beryllium copper.

Circle 145 on Reader Service Card

Switching Transistors

RCA offers three new junction transistors of the germanium p-n-p alloy type designed for use in high-current switching circuits of military and industrial computers, and in other "on-off" control circuits. Des-

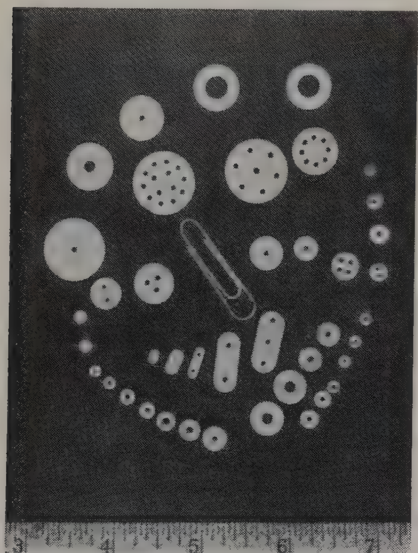


ignated as the 2N578, 2N579, and 2N580, these transistors feature a high maximum collector current rating of —400 milliampers. The 2N578, 2N579, and 2N580 have, respectively, minimum alpha-cutoff frequencies of 3, 5, and 10 *mc*, and minimum *dc* current transfer ratios of 10, 20, and 30 at the full collector current rating.

Circle 163 on Reader Service Card

Epoxy Preforms

Epoxweld 100, a new single component Epoxy preform used in automatic or production joining of metals, plastics, ceramics, glasses, and quartz is now available from Duramic Prod-



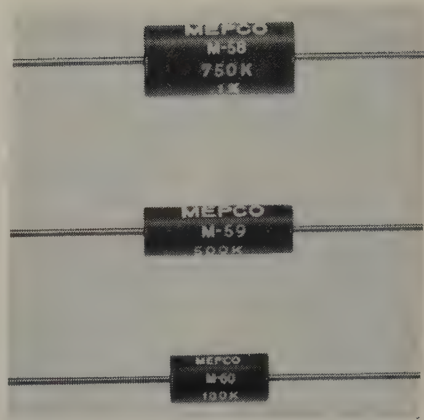
ucts Division, Technion Design & Mfg. Co. It is an unpolymerized epoxide resin available in preforms (pressed shapes) allowing fabricators to introduce a definite shape and amount of epoxy bonding material to accomplish a production assembly. Epoxweld 100 bridges the gap between expensive metallic solders and slow-to-handle 2-component epoxy adhesives.

Circle 168 on Reader Service Card

General Purpose Transistors

A new family of germanium general purpose audio (GPA) transistors has been announced by the Semiconductor Division of Motorola Inc. The transistors are under EIA numbers 2N650 through 2N655. The new devices feature a maximum junction temperature of 100° C., collector dissipation ratings of 200 milliwatts, and tightly controlled limits on other parameters. These transistors meet or exceed the mechanical and environmental requirements of military specification MIL-T-19500A.

Circle 130 on Reader Service Card



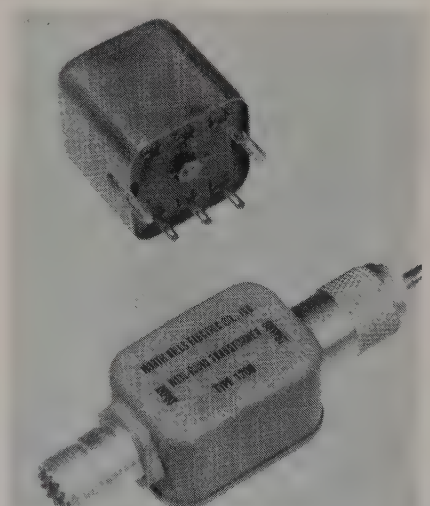
Miniature Wire Wound Resistors

Mepco, Inc. has added three new miniature units, the M58, M59 and M60, to their line of precision encapsulated wirewound resistors. They are produced in MIL styles 9444 AFRT 10, 11 and 12, in a power range of ⅛ to ⅓ watt at 125° C. Their operating range is —65° to 145° C. with a temperature coefficient of 0.003%/° C. All units are aged at high temperature to insure a stability of 0.03% or better.

Circle 158 on Reader Service Card

Wide Band Transformers

A new type of wide band transformer, type #1210, has been announced by North Hills Electric Company, Inc. Designed for operation over the frequency range from 100 *kc.* to 100 *mc.* with minimum insertion loss, these transformers may be used for step-up or step-down.



The impedance ratio is 600 ohms; 75 ohms. Applications include antenna matching, receiver and low power transmitter coupling, and use in many circuits where isolation, impedance matching, or step-up are required over a wide band.

Circle 166 on Reader Service Card

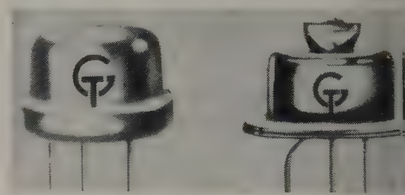
Single Crystal Germanium

Semimetals, Incorporated, nounces the availability of Sir Crystal Zone-Levelled germani This material features low dislo tion density and tight resistiv specifications. All resistivity ran are available immediately in prod tion quantities. The crystals can manufactured to specifications fr 0.1 to 30 ohm-centimeters, *n* or type.

Circle 134 on Reader Service Card

General Purpose Transistors

General Transistor announces t availability of 10 new general pu pose transistors, types 2N563 throu 2N572. Five of these germanium a



loyed junction units are packag in the JETEC 30 welded case an five are in the military case. The are recommended for application where tight parameter control an high reliability are desired. All uni can be supplied in full complianc with MIL-T-19500.

Circle 131 on Reader Service Card

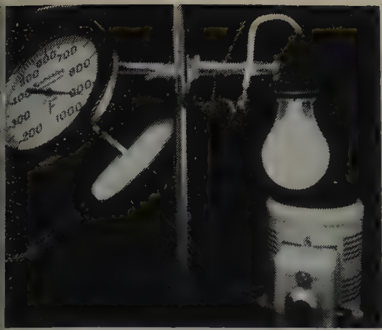
Switching Transistors

Five new Raytheon one amper switching transistors are now avail able to designers of computer, con trol and other equipment requirin this capability. These are *p-n-p* ger manium in the JETEC-30 packag Types 2N658, 2N659, 2N660 an 2N661 range in average cutoff fre quencies from 5 to 20 megacycles an their H_{fe} at base current of 10 milli amperes averages as high as 75. Fur thermore, characteristics are con trolled at high currents to provid improved performance. Type 2N66 has wider characteristics spread and is for use in less critical circuits.

Circle 159 on Reader Service Card

High Temperature Wire

Hitemp Wires, Inc. announces pilot production of ready-to-use flexible magnet wire with a conservative duty rating of 1000° F. for continuous operation. Hitemp will market the ceramic-coated wire under the trade name "CERAMA-TEMP." It will withstand temperatures to 1700° F. for a limited time, and requires no curing or heat treatment prior to use. The new product



ets the need expressed for some ...e by missile, aircraft and atomic ...rgy personnel. Its impact in these ...ds is predicted to be of paramount ...portance in the design and re...ble operation of new, high tem...ature devices.

Circle 156 on Reader Service Card

...ift Transistors

A series of four new germanium ...n-p drift transistors have been ...de available to manufacturers of ...litary and commercial radio-...quency equipment by Sylvania ...ectric Products Inc. The series is ...pected to have wide application in ...tertainment type portable re...ivers, since all four, designated ...247, 2N370, 2N371, 2N372, are de...gned for use both in AM broadcast band and short wave receivers. Important electrical features of these transistors are high gain at 1.5 *mc* to 20.0 *mc*, lower base resistance and reduced collector capacitance.

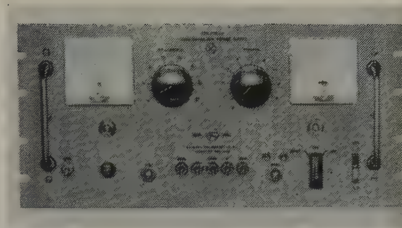
Circle 155 on Reader Service Card

Wire Tantalum Capacitors

Aerovox presents the first in a line of Tantalum capacitors, Type WT, wire tantalum units in subminiature sizes especially suitable for application in low voltage devices such as personal portable radios, hearing aids, transistorized circuits, etc. Type WT units are lead mounted, wire tantalum capacitors in polarized

types only. They are designed for use where *a-c* voltage is small with respect to *d-c* polarizing voltage. Type WT Tantalum capacitors are available from local Aerovox Distributors in standard voltage ratings of 1, 2, 4, 6, 8, 10, 20, 40 and 80 V dc.

Circle 138 on Reader Service Card



Transistorized Power Supply

Electronic Measurements Co. announces a new series of transistorized power supplies. The new units feature three-way short circuit protection, including a high-speed, all-electronic circuit breaker. Additional features are remote control and remote sensing. The remote sensing provision eliminates voltage changes at the load due to voltage drops in the leads. Regulation is 0.1% or 0.01 volt for extremes of line and load. Ripple is less than 0.001 volt.

Circle 148 on Reader Service Card

Transistor Transformers

Three new transistor transformers TA-15, TA-16 and TA-17 have been added to the Stancor line. TA-15 is an input transformer for matching low impedance microphones to a 2N156 or equivalent transistor. TA-16 is a driver transformer for single 2N156 or push-pull 2N278 transistors

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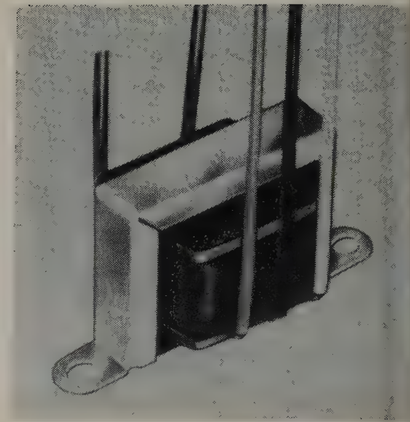


in Class B operation. TA-17 is modulation transformer for matc ing push-pull 2N278's Class B t Class C loads. All three units w have many other applications i transistor circuitry.

Circle 152 on Reader Service Card

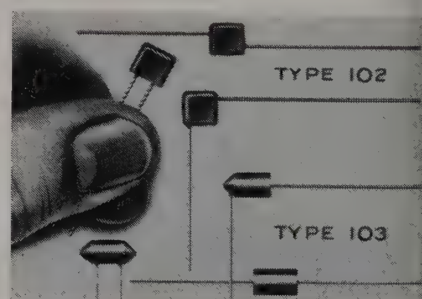
Computer Diodes

New types of high speed alloy junction computer diodes have recently been developed by Qutronic Semi-Conductor Corporation. Reverse recovery time of the Q5-100, Q5-250, Q10-200 and Q10-300 to 0.4 *ma* after switching from 1.6 *ma* forward current to −3.0 *v* reverse voltage applied through a 750 ohm loop resistance, is 5 millimicro-second maximum.

Circle 157 on Reader Service Card

Miniature WW Resistors

A new line of ultra-miniature wire-wound resistors was announced recently by Ultronix. Type 102 measuring only ¼" x ¼" x ⅛" can be obtained in values from 1 ohm to 1 megohm to tolerances of ±0.05%. Type 103 is 0.150" in diameter by 0.295" long and available in ranges from 1 to 500 k ohms with tolerances



of ±0.05%. Both types have operating temperatures from −65° C. to +125° C. The standard temperature coefficient is ±15 ppm. Power dissipation is 0.15 watt. For printed circuit work, lead spacing tolerance is maintained to ±0.005".

Circle 129 on Reader Service Card

Book Reviews

Title: Transistor Electronics

Authors: David Dewitt and Arthur Rossoff

Publisher: McGraw-Hill, 1957

The authors of this book state at the outset that the purpose of the book is to teach. With this in mind they develop the fundamental semiconductor processes from the quantum mechanics and energy band theories. This is followed by a rather thorough discussion of the *p-n* junction and the junction transistor.

The balance of the book is devoted more concisely to transistor electronics. A particularly good discussion of transistor power amplifiers of both the Class A and push-pull Class B types is found in Chapter seven. Chapter 8 is concerned with the application of feedback in transistor amplifier circuits with a review of circuits and methods. The small-signal high frequency behavior of transistors is reviewed together with many familiar switching circuits in the chapters that follow. Radio receiver applications of high frequency transistors are discussed and several of the new types of high frequency transistors are analyzed. The final chapter deals with transistor noise.

Transistor Electronics should prove to be an excellent text, since it is presented in a clear tutorial manner by authors with an obvious understanding of their subject.

Title: Mathematics For Electronics With Applications

Authors: Henry M. Nodelman and Frederick W. Smith

Publisher: McGraw-Hill Book Company, 1956

This book presents a very practical side of the mathematics peculiar to electronics. The authors devote the first two chapters to working out several sample problems illustrating how the calculus may be applied to their solutions.

The real value of this work lies in the later chapters. An interesting discussion of dimensions and a table of physical quantities and their equivalent units is found in Chapter 3 with the following chapter outlining a method of checking equations and predicting solutions.

The theory of determinants is reviewed extensively as is the method of network solution. Chapters 7 and 8 discuss matrix algebra and network solution by matrices as a logical outgrowth of determinants.

The balance of the book deals with a great variety of mathematical subjects including series representation of electronic functions, non-linear electronic devices, differential equations, LaPlace transformation and Boolean algebra.

This book is well written and will undoubtably find great popularity with the practising electronic engineer from both a content and presentation approach.

Title: Dictionary of Physics and Electronics

Authors: Walter C. Michels et al.

Publisher: D. Van Nostrand Company, Inc.

The combined efforts of sixteen well qualified authors have produced this comprehensive reference work. While the primary emphasis is in the fields of physics and electronics, representative topics in closely allied subject areas are also dealt with. Some of these are the fields of mathematics, chemistry, biology and engineering.

The scope of the work takes in the definitions of terms, statements of laws, relationships, equations, basic principles and concepts, and brief descriptions of widely used measuring and test equipment and apparatus.

The problem of presenting the material on a suitable level of difficulty has been met by a two-pronged attack wherever the authors considered it advisable. This approach involves the simultaneous presentation of both a simple definition or explanation along with a more rigorous treatment of the particular item. This approach makes the book valuable to both the advanced worker in the field and to the reader without an extensive mathematical background.

The subject matter has been taken from sixteen subject areas. Over 300 illustrations are included.

Industry News

The 2nd National Convention on Military Electronics was held June 16, 17, and 18 at Washington, D. C. Sponsored by the Professional Group on Military Electronics, IRE, its theme was Missiles and Electronics. Among the papers dealing directly with solid state devices were: "Infrared Detectors"— L. J. Neuringer, Raytheon; "Avalanche Noise in FN Junctions"—S. Sherr, S. King, General Precision Laboratory; "Some Design Considerations in the Application of Silicon Transistors to Voltage Mode Digital Circuitry"—James V. B. Cooper, William K. Mead, IBM; and, "A High Speed Transistor Shift Register for Operation up to 135° C"—J. L. Robinson, Philco.

Dr. William Shockley, Nobel prize winner from California, inaugurated the International Conference on Solid-State Physics in Electronics and Telecommunications on June 2 at the University of Brussels, Belgium, with an observation that "in science all workers are on an equal footing and their accomplishments are judged finally in the impartial court of nature which always operates by the same laws no matter whose experiments they govern."

"This symposium at the World's Fair is a step in a valuable direction. In the area of solid-state physics, scientists and engineers from all nations can establish an area of common understanding—an understanding based on the discovery and control of natural phenomena. Natural science is probably the field in which understanding can most easily be reached among workers of different backgrounds and native languages. A broader understanding between nations may thus be helped by increasing understanding and personal contact between their scientists."

First quarter factory sales of transistors increased 76 percent over the corresponding three month period in 1957 according to the Electronic Industries Association. Though March sales of transistors dropped from the February level, EIA recorded an increase over March 1957 by more than one million units. Factory sales of transistors in March totaled 2,976,843 with a dollar value of $6,795,427 compared with 3,106,708 transistors sold in February valued at $6,806,562 and 1,904,000 units worth $5,321,000 sold in March of last year. Cumulative sales of these semiconductor devices during the first quarter of this year totaled 9,038,798 valued at $20,306,372 compared with 5,125,300 transistors sold during the corresponding months of 1957 with a dollar value of $14,612,000, as the following EIA report for March shows:

	1958 Sales (units)	1958 Sales (dollars)	1957 Sales (units)
January	2,955,247	$6,704,383	1,436,000
February	3,106,708	6,806,562	1,785,000
March	2,976,843	6,795,427	1,904,000
TOTAL	9,038,798	$20,306,372	5,125,000

Two new products engineered by the General Electric Communication Products Department at Syracuse, N. Y., were shown for the first time at the annual convention of the Petroleum Industry Electrical Association and the Petroleum Electrical Supply Association here. These were a new hand-carried transistorized portable two-way radio as well as a new thermostatically-protected transistor-powered 100-watt mobile radio for vehicles. Both products illustrate the communication industry's advancement in the field of transistorization and both will have wide application in various types of business. The new portable is described as the first of its kind in the nation to include a tubeless receiver. The 100-watt mobile, according to General Electric, is the first offered for sale in the communications industry with thermostatic protection for transistors.

Texas Instruments Incorporated dedicated its new 310,000 sq ft plant of revolutionary design for the manufacture of transistors and other semiconductor devices on a 300-acre site on Monday, June 23, by using the signal from the American satellite Vanguard to cut the traditional ribbon. TI-made transistors are playing an important role in the instrumentation of the orbitting satellite. Dr. James R. Killian, Chairman of the President's Advisory Committee on Science, made the dedicatory address.

Raytheon's wide line of transistors has been increased by the addition of four *n-p-n* silicon types in the JETEC-30 package. These are 2N619, 2N620, 2N621 and 2N622. These four types are for low frequency service —the highest has an alpha frequency cutoff rating of about 400 kilocycles. 2N622 is a low noise type. Although not symmetrical to the Raytheon *p-n-p* silicon types these new *n-p-n* silicon types have similarities of help in complementary circuitry and all provide the ruggedness and dependability needed for critical applications. Variation of characteristics with temperature has been reduced.

The electronics industry's 1958 Medal of Honor was presented recently to H. Leslie Hoffman, president of the Hoffman Electronics Corp., of Los Angeles, for his many years of constructive leadership in a dynamic industry. Hoffman has been in the forefront of industry progress since electronics was represented by only one product—radio.

General Instrument Corporation, in a move to speed up its program of diversification in industrial and government electronics, announced recently the creation of a special Division for New Product Development—which will have at its disposal the research and engineering facilities of all the Company's branches—and named Lawrence R. Hill to head it up as Divisional Manager. Mr. Hill had been with Westinghouse Electric Corp. The new Division will apply itself to all electronic branches, but with particular emphasis on new products for the swiftly-growing industrial electronic market.

A new Industrial Semiconductor Distributor Organization designed to provide rapid, "off-the-shelf" transistor distribution and service across the nation has been established by the Lansdale Tube Company, division of Philco Corporation. According to Cyrus Warshaw, Lansdale Tube Company's General Sales Manager, carefully selected local industrial distributors are being appointed to stock the complete Philco transistor line in all leading industrial areas. Direct factory franchises are being established with key distributors for local sale and service of Philco transistors.

A price decrease of approximately 30% in the cost of solid-electrolyte tantalum electrolytic capacitors has been announced by the Sprague Electric Company. This is the second price reduction in 1958. At the time Sprague opened new production facilities at its semi-conductor plant at Concord, N. H., in January, it had dropped solid tantalum capacitor prices some 25%.

Lower prices for all grades of hyper-pure silicon were announced by Du Pont on May 11 coincident with the start-up of the nation's first full-scale silicon plant near Brevard, N. C. Reductions range from \$5 to \$40 a pound, retroactive to May 1, according to Dr. J. B. Sutton, specialty products sales manager for the company's Pigments Department.

For the second time in less than six months, Delco announces substantially lower prices. Now, prices on some sample quantities of high-power transistors have been cut as much as 27%. Production quantity prices have been reduced also—up to 28%.

Index to Advertisers

All advertisements, New Prods & Literature are numbered for your convenience

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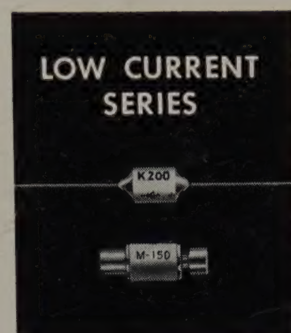
Voltage Drop 1.25V
Approx. Weight
(Ounces) . . . . .2 oz.

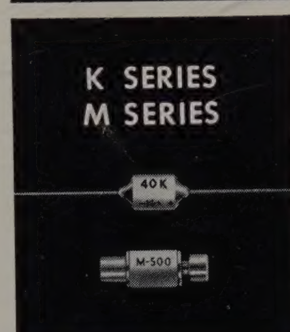


SPECIFICATIONS

D. C. Current
Range . . . . . .15A(M)—.2A(K)
Peak Inverse
Voltage Range 360V
Approx. Rectifier
Voltage Drop 1.5V
Approx. Weight
(Ounces) . . . . .2 oz.

SPECIFICATIONS

D. C. Current
Range . . . . . 1.5A(L)—5A(LF)
Peak Inverse
Voltage Range 100V to 400V
Approx. Rectifier
Voltage Drop 1.5V
Approx. Weight
(Ounces) . . . . .35 oz.



SPECIFICATIONS

D. C. Current
Range . . . . . .5A(M)—.75A(K)
Peak Inverse
Voltage Range 100V to 600V
Approx. Rectifier
Voltage Drop 1.5V
Approx. Weight
(Ounces) . . . . .2 oz.

SPECIFICATIONS

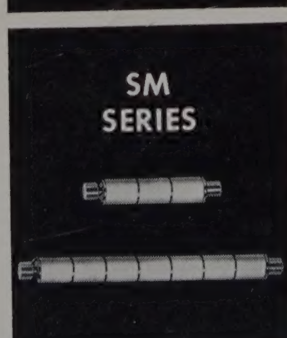
D. C. Current
Range . . . . . . 20A to 200A
Peak Inverse
Voltage Range 50V to 400V
Approx. Rectifier
Voltage Drop 1.25V
Approx. Weight
(Ounces) . . 1.3 oz. to 7.0 oz.

SPECIFICATIONS

D. C. Current
Range . . . . .5A to 15A
Peak Inverse
Voltage Range . . 50V to 600V
Approx. Rectifier
Voltage Drop 1.5V
Approx. Weight
(Ounces) . . .15 oz. to 1.5 oz.

SPECIFICATIONS

D. C. Current
Range . . .25A(HW)—.75A(FW)
Peak Inverse
Voltage Range 1600V to 4500V
Approx. Rectifier
Voltage Drop . . . . . 8V to 10V
Approx. Weight
(Ounces) . . . . . 4 oz. to 8 oz.



SPECIFICATIONS

D. C. Current
Range . . . . . .325A to .45A
Peak Inverse
Voltage Range 800V to 2800V
Approx. Rectifier
Voltage Drop . . . . 2V to 15V
Approx. Weight
(Ounces) . . . . .3 oz. to .9 oz.

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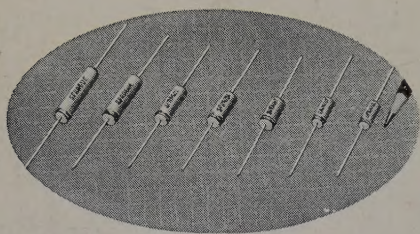
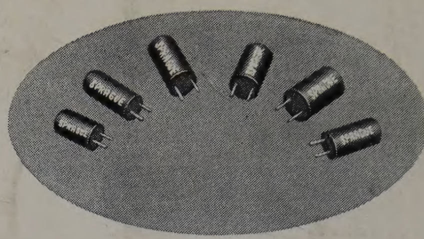


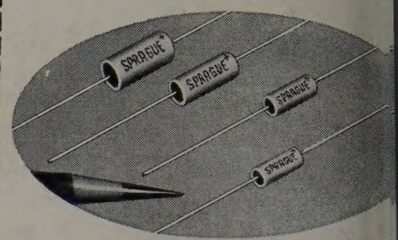
LITTL-LYTIC* CAPACITORS

Sprague's new Type 30D hermetically-sealed aluminum-encased capacitors are the *tiniest* electrolytic capacitors made to date . . . and their performance is better than ever. Their remarkable reliability is the result of a new manufacturing technique in which *all the terminal connections are welded. No pressure joints . . . no "open circuits" with the passage of time.* And check this for ultra-low leakage current: for a 2 μf, 6 volt capacitor . . . only 1.0 μa max.; for a 300 μf, 6 volt capacitor . . . 3.5 μa max.! Engineering Bulletin No. 3110 gives the complete story. 85°C standard.



VERTI-LYTIC* CAPACITORS

These space-saving Type 89D 'lytics are designed for easy manual upright mounting on printed wiring boards. Keyed terminals assure fast mounting and correct polarity. No reworking on the assembly line. Sturdy pre-molded phenolic shell with resin end-fill gives excellent protection against drying-out of the electrolyte or the entry of external moisture. The phenolic case eliminates the necessity for additional insulation. Reasonably priced for mass production receivers. Engineering Bulletin No. 3060 lists standard ratings with performance data.



Cera-lytic* CAPACITORS

The ideal capacitor for appl cations where low cost is the pr mary consideration is Sprague new Type 31D. Capacitor se tions are housed in a dense steati tube with resin end-fill to provid protection against mechanica damage and atmospheric humid ity. This construction results i excellent capacitor performanc for all miniature electronic cir cuits. Size for size, they're th smallest the industry has pro duced in a ceramic-cased alu minum electrolytic. Engineering Bulletin No. 3010 details stand ard ratings and gives perform mance data.

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